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PLASMA ETCHING DEVICE
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Plasma Etching Device

Technical Field

The present invention pertains to a plasma etching device, and more specifically, it relates to a plasma etching device that can freely control plasma density generated on the surface of a base, and/or a self-bias potential on the surface of the base.

Background Art

Recently, accompanying the increase in chip size of DRAM, MPU, and the like there has also been a tendency to increase the diameter of a silicon substrate used as a substrate for these devices. In the field of semiconductor manufacture, etching of an oxide film, polysilicon, or the like is one of the most important steps, but with a normal parallel RIE device that was used formerly it was not possible to achieve plasma performance (e.g., a process pressure of 50 mTorr or less, ion saturation current of at least 1 mA/cm^2 (electron density of at least 1×10^{10} cm^{-3}) required for machining a fine pattern to 1.0 μm or less. In order to solve this problem, a plasma source introduced into a magnetic field was developed, and as one example of a device containing this plasma source, a magnetron plasma etching device using a dipole ring magnet (hereinafter referred to as DRM) is well known (JP H6-37054A, Figures 24 and 25).

However, with a magnetron plasma etching device using the above-mentioned DRM, generation of low pressure high density plasma is possible, but it is difficult to control plasma generated on the base with high precision. That is, by introducing a horizontal magnetic field onto the base, it was difficult to make the plasma density uniform and making the self-bias potential uniform on the base. At the present, a scheme for causing the magnetic field to have a slope (JP S62-21062A) and causing the magnetic field introduced into a processing space to be rotated (JP S61-208223A) have been adopted as methods of making the plasma density and self-bias potential uniform. However, in the method of JP S62-21062A, there was a problem because the process pressure and the like varied, the optimal magnetic slope also varied. On the other hand, /2
in the method of JP S61-208223A, apparently the plasma density could be made uniform for a base in a processing space, but a mechanism for causing rotation of the magnetic field was essential, and it was difficult to make the device small.

It is an object of the present invention is to provide a plasma etching

[1]Number in the margin indicates pagination in the foreign text.

device capable of etching with respect to a base uniformly, and without charge-up damage (generated as a result of potential deviation) independently of pressure and without causing rotation of magnetic field applying a means by making the density of plasma generated on a surface of the base uniform, and making a self-bias potential uniform.

Disclosure of the Invention

A 1st plasma etching device of the present invention characterized by being provided with two parallel plate-type electrodes I and II, and a means for applying high frequency power connected to the electrode I and electrode II, with a base to be subjected to etching processing using plasma being mounted on a surface of the electrode I opposite the electrode II, and further being provided with a means for applying a magnetic field being horizontal with respect to the surface of the base to be subjected to plasma etching, and being unidirectional; the plasma etching device further comprising an auxiliary electrode at least on an upstream side, with respect to the base, of a flow of electrons generated by the magnetic field-applying means; and the auxiliary electrode comprising a local electrode arranged on the side facing the electrode II and a means for adjusting impedance provided at a part of the local electrode to be electrically connected with the electrode I.

A 2nd plasma etching device of the present invention characterized by being provided with two parallel plate-type electrodes electrode I and electrode II, and a means for applying high frequency power connected to the electrode I and electrode II, with a base to be subjected to etching processing using plasma being mounted on a surface of the electrode I opposite the electrode II, and further being provided with a means for applying a magnetic field being horizontal with respect to the surface of the base to be subjected to plasma etching, and being /3 unidirectional; the electrode II comprising a central portion electrically connected to ground, and an outer peripheral portion connected to a high frequency power supply capable of being controlled independently of a high frequency power supply connected to the electrode I.

A 3rd plasma etching device of the present invention characterized by being provided with two parallel plate-type electrodes electrode I and electrode II, and a means for applying high frequency power connected to the electrode I and electrode II, with a base to be subjected to etching processing using plasma being mounted on a surface of the electrode I opposite the electrode II, and further being provided with a means for applying a magnetic field being horizontal with respect to the surface of the base to be subjected to plasma etching, and being unidirectional; the plasma etching device further comprising an auxiliary electrode at least on an upstream side, with respect to the base, of a flow of electrons generated by the magnetic field-applying means, with the auxiliary electrode including a local electrode being arranged on the side facing the electrode II and means for adjusting impedance provided at a part of the local electrode to be electrically connected with the electrode I, and the electrode II

comprising a central portion electrically connected to ground, and an outer peripheral portion connected to a high frequency power supply capable of being controlled independently of a high frequency power supply connected to the electrode I.

A 4th plasma etching device of the present invention characterized by being provided with two parallel plate-type electrodes electrode I and electrode II, and a means for applying high frequency power connected to the electrode I and electrode II, with a base to be subjected to etching processing using plasma being mounted on a surface of the electrode I opposite the electrode II, and further being provided with means for applying a magnetic field being horizontal with respect to the surface of the base to be subjected to plasma etching, and being unidirectional; an auxiliary electrode of a ring body being provided at a peripheral section of the base; the auxiliary electrode including a local electrode arranged on the side facing the electrode II and means for adjusting impedance provided at a part of the local electrode to be electrically /4
connected with the electrode I; and the impedance of the ring body at a section corresponding to an upstream side in a flow of electrons generated by the magnetic field-applying means being lower than at other sections.

A 5th plasma etching device of the present invention characterized by being provided with two parallel plate-type electrodes electrode I and electrode II, and a means for applying high frequency power connected to the electrode I and electrode II, with a base to be subjected to an etching treatment using plasma being mounted on a surface of the electrode I opposite the electrode II, and further being provided with a means for applying a magnetic field being horizontal with respect to the surface of the base to be subjected to plasma etching, and being unidirectional. The electrode II being composed of a central portion electrically connected to ground, and a ring body outer peripheral portion connected to a high frequency power supply capable of being controlled independently of a high frequency power supply connected to the electrode I; the impedance of the aforesaid ring body at a section corresponding to an upstream side in a flow of electrons generated by the magnetic field-applying means being lower than at other sections.

However, the impedance of the plasma etching device of the 1st, 3rd and 4th plasma etching devices of the inventions mentioned above refers to the junction impedance between the auxiliary electrode and the electrode I.

Brief Description of the Drawings

Figure 1 is a schematic drawing showing one example of a plasma etching device provided with an auxiliary electrode pertaining to the present invention.

Figure 2 is a plan view of electrode I viewed from the side of electrode II in Figure 1.

Figure 3 is a plan view showing the state where the auxiliary electrode is provided over electrode I in Figure 2.

Figure 4 is a plan view of electrode II viewed from the side of electrode I in Figure 1.

Figure 5 is a plan view showing magnetic field-applying means in Figure 1.

Figure 6 is a schematic cross sectional view showing a positional relationship between the electrode I, the auxiliary electrode and a base.

Figure 7 is a model diagram of electron flow pertaining to the present invention, and shows a case in which high frequency is only applied to an electrode outside the structure of electrode II. /5

Figure 8 is a model diagram of electron flow of a conventional example, and shows a case in which high frequency is applied to both an electrode inside and an electrode outside the structure of electrode II.

Figure 9 is a schematic cross sectional view showing a case in which only an electrode outside the structure of the electrode II of Figure 4 is provided close to the electrode I.

Figure 10 is a graph showing plasma density observed in a case in which only an E pole side local electrode 103e is cathodized.

Figure 11 is a graph showing plasma density observed in a case in which only a W pole side local electrode 103w is cathodized.

Figure 12 is a graph showing plasma density observed in a case in which only an N pole side local electrode 103n is cathodized.

Figure 13 is a graph showing plasma density observed in a case in which only a S pole side local electrode 103s is cathodized.

Figure 14 is a graph collectively showing self-bias potential for each of the conditions of Figures 10 to 13.

Figure 15 is a graph collectively showing the results of plasma density shown in Figures 10 to 13.

Figure 16 is a graph showing a self-bias potential observed in a case of using a capacitor of various capacitances as a means for adjusting impedance of the E pole side.

Figure 17 is a graph showing plasma density observed in a case of using a capacitor of various capacitances as a means for adjusting impedance of the E pole side.

Figure 18 is a graph showing results of Vdc observed in a case in which high frequency is applied to the all surfaces 106 and 107 of the electrode II.

Figure 19 is a graph showing results of Vdc observed in a case in which high frequency is applied to a central portion 106 of the electrode II.

Figure 20 is a graph showing results of Vdc observed in a case in which high frequency is applied to an E pole side outer peripheral electrode 107e of the electrode II.

Figure 21 is a graph showing results of Vdc observed in a case in which high frequency is applied to all outer peripheral electrodes 107 of the electrode II. /6

Figure 22 is a graph showing results of Vdc observed in a case in which high frequency is applied to all outer peripheral electrodes of the electrode II except a W pole side outer peripheral electrode 107w.

Figure 23 is a graph showing results of Vdc observed in a case in which high frequency is only applied to an E pole side outer peripheral electrode 107e of the electrode II.

Figure 24 is a schematic diagram showing a magnetron plasma etching device using a conventional dipole ring magnet (DRM).

Figure 25 is a schematic diagram showing magnetic field distribution formed by the dipole ring magnet (DRM) in the device of Figure 24.

Figure 26 is a schematic cross sectional view showing various forms of the auxiliary electrode 102 shown in Figure 1.

Figure 27 is a schematic plan view of the electrode I and auxiliary electrode viewed from the electrode II side, and shows a relative positional relationship between local electrode 103 constituting the auxiliary electrode 102 shown in Figure 1 and the base 108.

Figure 28 is a schematic plan view for describing the arrangement of the local electrode and the base, and shows a case in which a local electrode constituting the auxiliary electrode provided on an upstream side of at least a flow of electrons generated by magnetic field-applying means has a size covering the upstream side of the electron flow, viewed from the position of the whole of the base.

Figure 29 is a schematic plan view showing the relative quadruplicate arrangement of the local electrode 103 and the base 108.

Figure 30 is a schematic plan view of the electrode I as viewed from

the electrode II side, and is for describing a probe arrangement.

Figure 31 is a graph showing results upon measuring the plasma density Ji, which pertains to Practical Example 4.

Figure 32 is a schematic cross sectional view of a parallel plate-type plasma etching device without an auxiliary electrode, which pertains to Practical Example 5.

Figure 33 is a schematic cross sectional view showing the relative sextuple arrangement of electrode II 105 and electrode I 101, which pertains to Practical Example 5.

Figure 34 is a schematic plan view of electrode I, viewed from the electrode II side to describe a probe arrangement. /7

Figure 35 is a graph showing results upon measuring the self-bias potential Vdc, which pertains to Practical Example 5.

Figure 36 is a schematic plan view of electrode II viewed from the electrode I side, to describe various forms of the outer peripheral portion 107 constituting electrode II.

(Explanation of the Codes)

100: chamber;
101: electrode I;
101a; section holding base of electrode I (susceptor);
102: auxiliary electrode;
102n: N pole side local electrode;
102s: S pole side local electrode;
102e: local electrode provided on an upstream side of at least a flow of electrons, e.g., E pole side local electrode;
102w: W pole side local electrode;
103: local electrode;
104: means for adjusting junction impedance;
105: electrode II;
106: central portion constituting electrode II (inner electrode);
107: outer peripheral portions constituting electrode II (outer peripheral electrode);
107', 107": members;
108: base;
109: magnetic field-applying means;
110: high frequency power source;
111: screw holes for joining auxiliary electrode;
112: screw for joining auxiliary electrode;
113: probe;
114: shower jacket;
116: single layer film or multiple layer film comprising a material having a different conductivity to the local electrode and the electrode

I;
117a: cavity provided at an inner part of the local electrode 103;
117b: cavity provided close to a boundary of the local electrode 103 and electrode I 101;
118: thin film comprising insulating material provided between the local electrode 103 and electrode I 101;
119: capacitor provided between the local electrode 103 and electrode I 101;
509: DRM (dipole ring magnet);
515: magnetic field;
2401: vacuum container;
2402: 1^{st} electrode;
2403: wafer;
2404: gas introduction inlet;
2405: high frequency power source;
2406: discharge port;
2407: 2^{nd} electrode;
2411: insulating material; /8
2412: gate valve;
2413: dipole ring;
2414: matching circuit;
2416: protecting ring;
2417: cooling pipe;
2423: auxiliary magnet;
2450: quartz window;
2451: optical sensor;
2452: monitor;
2532: wafer center;
2533 wafer edge

Best Mode for Carrying Out the Invention

Figure 1 is a schematic drawing showing one example of a plasma etching device provided with an auxiliary electrode pertaining to the present invention.

In Figure 1, 100 is a chamber; 101 is an electrode I; 101a is a part (susceptor) of the electrode I on which a base is mounted; 102 is an auxiliary electrode; 103 is a local electrode; 104 is junction impedance-adjusting means; 105 is an electrode II; 106 is a central portion electrically grounded; 107 is an outer peripheral portion connected to a high frequency power source (not shown); 108 is a base; 109 is magnetic field-applying means; 110 is a high frequency power source; 112 is a screw for joining the auxiliary electrode; and 114 is a mechanism for introducing process gas comprised of a shower head built into the electrode II.

Figure 2 is a plan view of the electrode I as viewed from the electrode II side in Figure 1. Figure 3 is a plan view showing the state where the auxiliary electrode is provided over the vicinity of the outer edge of electrode I in Figure 2. Figure 4 is a plan view of electrode II as viewed

from the side of electrode I in Figure 1. Figure 5 is a plan view showing magnetic field-applying means in Figure 1.

The auxiliary electrode 102 pertaining to the present invention is mounted for use in a plasma etching apparatus which is provided with two parallel plate-type electrodes I 101 and II 105, as shown in Figure 1, has a based to be subjected to a treatment, such as etching, using a plasma, on a face of the aforesaid electrode I 101 opposite the aforesaid electrode II 105, and provided with a means 109 for applying a directional magnetic field horizontally relative to a surface of the aforesaid base 108 to be subjected to plasma etching.

Figure 5 is a plan view showing the base 108 and a DRM (dipole ring magnet) 509 functioning as the magnetic field-applying means 109, as viewed from the side of electrode II. With the plasma etching device in Figure 1, as the magnetic field-applying means 109, as shown in Figure 5, /9
a DRM (dipole ring magnet) 509 is used as the means for applying a magnetic field 515 having directionality horizontally relative to the surface of the base 108 to be subjected to plasma etching.

The auxiliary electrode 102 shown in Figure 1 is provided at least on an upstream side of at least a flow of electrons generated by the magnetic field-applying means, relative to the base, as shown in Figures 2 and 3. The auxiliary electrode 102 comprises a local electrode 103 arranged on the opposite side of the electrode II 105, and an impedance-adjusting means 103 provided at a section of the local electrode electrically connected to the electrode I. However, Figures 2 and 3 show an example where an impedance-adjusting means (not shown) has been provided between the local electrode 103 and the electrode I 101, so as to overlap below the local electrode 103.

Figure 27 is a schematic plan view as viewed from the electrode II side, and shows a relative positional relationship between the local electrode 103 constituting the auxiliary electrode 102 shown in Figure 1 and the base 108. In Figure 27, an example is shown in which the impedance-adjusting means (not shown) is provided between the local electrode 103 and the electrode I 101 so as to overlap below the local electrode 103, but it also is possible to employ other methods of provision, such as that shown in Figure 26.

The relative positional relationship between the local electrode 103 pertaining to the present invention and the base 108 will now be described in detail with reference to Figure 27.

Figure 27(a) shows a case in which a local electrode constituting an auxiliary electrode is a 1st local electrode 103a comprising a conductive material provided only on an upstream side (E pole side) of a flow of electrons generated by the magnetic field-applying means.

Figure 27(b) shows a case in which a local electrode constituting

an auxiliary electrode comprises a combination of a 2nd local electrode 103b comprising a conductive material provided at least on an upstream side (E pole side) of a flow of electrons generated by the magnetic field-applying means, and a 3rd local electrode 103c comprising an insulating material provided except on the upstream side.

Figure 27(c) shows a case in which a local electrode constituting an auxiliary electrode comprises a combination of a 4th local electrode 103d comprising a conductive material that is wide at least at an upstream side of a flow of electrons generated by the magnetic field-applying means and narrow except on the upstream side, and a 5th local electrode 103e comprising an insulating material provided outside a region where the 4th electrode is narrow, as viewed from the base side.

Figure 27(d) shows a case in which a ring body auxiliary /10
electrode is provided at an edge section of the base, and the auxiliary electrode is composed of a local electrode arranged on the opposite side of the electrode II and an impedance-adjusting means provided at a section of the local electrode electrically connected to the electrode I, and where the impedance of the ring body is lower in at least a part (the local electrode 103f part) equivalent to an upstream side of a flow of electrons generated by the magnetic field-applying means than at another section (the local electrode 103g part).

As shown in Figures 28(a) to (d), as viewed from the all the positions of the base, the local electrodes constituting the auxiliary electrode above preferably have such as size that they cover the upstream side of the electron flow (E pole side in Figure 28). Figure 28(a) shows a case in which a substantially semicircular section of the base is surrounded by the local electrode; Figure 28(b) shows a case in which the base is surrounded by the local electrode up to the same extent as the width of the base, as viewed from the upstream side of the electron flow; Figure 28(c) shows a case in which more than a semicircular section of the base is surrounded by the local electrode; and Figure 28(d) shows a case in which the base is completely surrounded by the local electrode. By providing such a large electrode, it is possible to cause a uniform parallel flow of electrons in one direction over the entire surface of the base; hence, the surface distribution of plasma density for the base becomes uniform and it is possible to carry out a uniform etching treatment on the base.

The chamber 100 in Figure 1 functions as a decompression vessel. Although an Al alloy or the like is used at the wall surface material for the chamber 100, in a case of etching an oxide film, and the like a material that has been nitride processed (e.g., AlN) is preferred in consideration of the fact that moisture released from the chamber wall surface or the like is a main reason for increased resist etching rate. This not only applies to the chamber wall surfaces. Material of the electrodes and parts inside of the chamber must also be formed from a material that, as much as is possible, does not release moisture, etc. Glassy carbon, SiC, or the like can be cited as the conductive material, while AlN, SiN,

or the like are cited as the insulating material. Selection of material is made taking into consideration the thermal conductivity, the electric field strength ratios at the surfaces, etc.

Electric power for generating plasma is supplied from a high frequency power source 110 to the electrode I 101. The electrode I 101 has a susceptor 101a at a position for holding the base (e.g., an Si wafer) 108 centrally, and the diameter of the susceptor is wafer size. In addition, an auxiliary electrode 102 is mounted at an outside section of the electrode I 101 at a position separated from the base 108. The auxiliary electrode /11 102 is composed of the local electrode 103 provided on at least an upstream side of a flow of electrons generated by the magnetic field-applying means 109 with respect to the aforesaid base 108, and the impedance-adjusting means 104 provided at a section of the local electrode 103 electrically connected to the electrode I 101.

Each of the members constituting the etching device pertaining to the present invention will now be described in detail.

<u>(1) Auxiliary electrode 102</u>

With the auxiliary electrode 102 pertaining to the present invention, the size of the junction impedance with the electrode I 101, the size of the local electrode 103, the position at which the local electrode 103 is provided, and the height difference between the local electrode 103 and the base 108 are extremely important. Differences between the prior art and the present invention will now be described with respect to these points.

<u>(1-1) Size of the junction impedance with the electrode I 101</u>

Even with a conventional etching device, there were cases where a ring body or an electrode, which was separate from the electrode I, was provided on the outer peripheral portion of an electrode corresponding to the electrode I 101 of the present invention, e.g., at a position of the auxiliary electrode 102. However, with an electrode, which is separate from the electrode I 101 of the conventional etching device, only the following two uses existed: (1) the whole electrode was composed of a conductive material, there was an electrically conductive path to an electrode corresponding to the electrode I 101 of the present invention, and the surface area of the cathode is widened and plasma uniformity is maintained, or (2) the whole electrode was composed of a material that does not pass high frequencies (e.g., quartz, for example), the circumference of a susceptor on which the base was mounted was insulated, and there was an effective power inputted to the susceptor increased.

On the other hand, the auxiliary electrode 102 pertaining to the present invention is composed of the local electrode 103 comprising a conductive material similar to the electrode I 101, and the impedance adjustment means 104 provided at a part of the local electrode 103 connected

electrically to the electrode I 101. By varying the junction impedance for the electrode I 101 with the local electrode 103, it is possible to control the penetration of high frequencies into the surface of the local electrode (e.g., a surface where the auxiliary electrode 102 is exposed to plasma), which is significantly different than in the past. For example, the auxiliary electrode 102 of the present invention is provided with a thin film 118 as a capacitor and a capacitor 119 between the local electrode 103 and the electrode I 101, as shown in Figure 26(e), and this thin film 118 and capacitor 119 can be implemented using a structure comprising /12
the impedance-adjusting means 104.

As the local electrode 103 comprising a conductive material, Al, Si, SiC, Cu or stainless steel (hereinafter referred to as SUS) that has not been, e.g., surface processed, and materials where either an alumite treatment, fluoride static body treatment, an MgO coating, or the like has been conducted on the surfaces of the these materials are used ideally. Also, SiO_2, Teflon, and the like can be cited for the local electrode 103 comprising an insulating material.

Figure 26(a) shows a case in which the local electrode 103 has a region with a narrow surface area for coming into contact with the electrode I 101, and this region constitutes the impedance-adjusting means 104. In Figure 26(a), a prescribed junction impedance can be obtained by adjusting the surface area of the concerned region.

Figure 26(f) shows a case in which the local electrode 103 has an uneven region for coming into contact with the electrode I 101, and this region constitutes the impedance-adjusting means 104. Figure 26(g) shows a case in which the electrode I 101 has an uneven region for coming into contact with the local electrode 103, and this region constitutes the impedance-adjusting means 104. Figure 26(h) shows a case in which two surfaces of the local electrode 103 have uneven regions for coming into contact with the electrode I 101, and these regions constitute the impedance-adjusting means 104. Figure 26(i) shows a case in which, in the structure of Figure 26(f), the base 108 is arranged on a section 101a (susceptor) of the electrode I for mounting the base so as to protrude in the direction of the local electrode 103. In Figures 26(f) to 26(h), a prescribed junction impedance can be obtained by adjusting the shape of the uneven regions or the surface area where the unevenness is provided. Particularly, in Figure 26(i) a featured characteristic where it is difficult to carry out etching of a side surface of the section 101a (susceptor) of the electrode I where the base is mounted opposite the local electrode 103 can be held together.

Figure 26(b) shows a case in which there is a single layer film or a multilayer film 116 comprising a material having a specific conductivity different from the local electrode and the electrode I between the local electrode 103 and the electrode I 101, and this film 116 constitutes /13
the impedance-adjusting means 104. In Figure 26(b), a prescribed junction impedance can be obtained by adjusting the dielectric constant and film

thickness of a single layer film, or adjusting the dielectric constant, film thickness, or deposition sequence of each of the films constituting a multilayer film.

Figure 26(c) shows a case in which a cavity 117a is provided inside the local electrode 103, and this cavity 117a constitutes the impedance-adjusting means 104. Figure 26(d) shows a case in which a cavity 117b is provided in the vicinity of the interface between the local electrode 103 and the electrode I 101, and this cavity 117b constitutes the impedance-adjusting means 104. In Figures 26(c) and 26(d), a prescribed junction impedance can be obtained by adjusting the size of the cavity 117. In addition, a function of adjusting the impedance between the local electrode 103 and the electrode I 101 is also achieved if the inside of the cavity 117 is either of a vacuum, an inert gas, or a material having a different dielectric constant from the aforesaid local electrode and the aforesaid electrode I.

Figure 26(e) shows a case in which the thin film 118 and the capacitor 119 are provided between the local electrode 103 and the electrode I 101 as a capacitor, and this thin film 118 and capacitor 119 constitute the impedance-adjusting means 104. In Figure 26(e), a prescribed junction impedance can be obtained by adjusting the capacitance of the capacitor 119. In addition, in Figure 26(e), as another example, the whole auxiliary electrode 102 can be composed of an insulating material (e.g., Teflon and SiO_2), and a connection terminal comprising a capacitor can be inserted into the auxiliary electrode (this example is not shown). By employing this junction impedance-adjusting means 104, a prescribed capacitance can be provided between the electrode I 101 and the auxiliary electrode 102. Moreover, according to this technique, it also is possible to suitably modify the junction impedance thereof.

Any of Al, Cu, Si, SiC, or glassy carbon is used ideally as a material for the local electrode 103.

<u>(1-2) Size of the local electrode 103</u>

The width of the local electrode 103 (in a case in which the local electrode 103 and the impedance-adjusting means 104 have the same width, this means the width of the auxiliary electrode 102 can be reduced to 20 mm with the device of the present invention, whereas, with a /14
conventional device, it must be about 30 to 40 mm in order to achieve the desired functions. Consequently, in the present invention, it is possible to reduce the diameter of the local electrode 103 to about 40 mm.

In addition, in Figure 1, the size of the base 108 comprising a wafer is 200 mm, but the required size of the local electrode pertaining to the present invention does not vary significantly even if the size of the base 108 becomes 300 mm, as long as processing conditions remain constant. Therefore, it is possible to reduce the internal diameter of the chamber at that part, and it will be possible to handle progressively increased

diameter bases in the future without making the chamber size extremely large. Figure 23 shows a relationship between the width of the local electrode 103 and the base in-plane distribution of plasma density. From Figure 23, it is understood that with a pressure of, e.g., 20 mTorr, if the width of the local electrode 103 is 20 mm, the drop in the plasma density at the E pole side can be reduced.

(1-3) Position at which the local electrode 103 is provided

With the plasma etching device of Figure 1, as shown in Figure 5, a DRM (dipole ring magnet) capable of applying a magnetic field 515, being horizontal with respect to a surface of the base 508 to be subjected to plasma etching and which is unidirectional, is employed as the means for applying a magnetic field 109. With such a DRM, since the electrons move around lines of magnetic force inside of plasma sheath on the base, it is possible to generate highly dense plasma. In this case, since the E pole side in Figure 5 is upstream from the electron flow, it is extremely important that the auxiliary electrode 102 exists at the E pole side for the following reasons.

First of all, the thing to note is the way in which electrons move. Electrons move in a spiral movement (cycloid movement) while winding around lines of magnetic force, and at that time, the turning radius of the electrons can be expressed by the following equation:

Larmor radius (mm): $$R = \frac{33.7 \cdot (Vdc)^{1/2}}{B}$$

Vdc is the self-bias potential and B is the magnetic flux density. From this equation, it is understood that if Vdc=200V and the magnetic flux density=200 G, R will be about 2 mm. Accordingly, electrons rotate around in a space as close as possible to the cathode without dispersing and this is fitted into an ion sheath. If electrons fly out from the ion sheath, the electric field (self-bias) disappears and the cycloid movement does not arise.

Figure 6 is a schematic cross sectional drawing showing a positional relationship between the electrode I 101, the auxiliary electrode 102 and the base 108. The auxiliary electrode 102 of Figure 6 shows a case in which the local electrode 103 and the impedance-adjusting means 104 have the same width. Sections that are not shown in this drawing basically correspond to sections in Figure 1. As will be understood from Figure 6, in order to stably realize the above-mentioned electron movement, it is important to provide the auxiliary electrode 102e having a suitable junction impedance with the electrode I at the E pole side which is upstream from the electron flow. By disposing the auxiliary electrode 102e, a smooth electron flow (i.e., continuous movement in the direction shown by the dotted lines and arrows in Figure 6) is made possible even at an outer peripheral region of the base 108 on the auxiliary electrode 102e side. As a result, it is possible to make the etching rate at the outer peripheral /15

region of the base 108 on the auxiliary electrode 102e side the same as that at the center of the base. In that case, it also is possible to finely adjust the impedance using a variable capacitor.

In Figure 3, the reason why the auxiliary electrode 102 has been divided into 4 sections is for an experiment which will be described later; it may be a single integral electrode.

With the etching device using the conventional DRM, since it is intended to make the etching rate for the base uniform, the magnetic field to be applied is sometimes rotated. However, if the base can be treated in a state where the magnetic field is not rotated, by positioning the auxiliary electrode 102 on the upstream side of the electron flow, the input power efficiency is further raised and it is possible to increase the density of the generated plasma. Figure 3 is a plan view showing the arrangement of the auxiliary electrode 102 as viewed from the electrode II side. With respect to the local electrode except the E pole side of the external magnetic field, since distribution of plasma density on the base has no relation to the presence or absence of the local electrode, high frequency may be applied to the E pole side and other sections brought into a totally insulated state. As a consequence, when the base is processed without rotating the magnets, it is possible to use a local electrode having a shape where only the E pole side is isolated. Also, it goes without saying that the divided shape of the local electrode 103 is not limited to this example. In short, it is essential to have a shape enabling compensation for a density decrease on the upstream side of the electron flow. Moreover, a base treatment without rotating the magnetic field becomes possible with plasma uniformity for the first time according to the present invention.

Therefore, since the auxiliary electrode 102 of the invention of the present application has the above-mentioned structure, it is possible to obtain a plasma etching device in which there is no lowering of the density of generated plasma and it is possible to expect uniform plasma density. /16

(1-4) Difference in height between surface of local electrode 103 constituting auxiliary electrode 102 to be exposed to plasma, and surface of base 108

A case in which there is a difference between the height of the surface of the local electrode 103 and the height of the surface of the base 108 will now be discussed. In a case in which the surface of the local electrode is higher than the surface of the base (Figure 6(a)), as long as it is within the width of the ion sheath, the movement of electrons generated at the surface of the local electrode reaches the surface of the base, but conversely, in a case in which the surface of the local electrode is lower than the surface of the base (Figure 6(b)), with only a 0.5 mm difference in height, the movement of electrodes is interrupted at the boundary of the local electrode and the base. Specifically, the movement of electrons starts correctly at the edge surface of the susceptor, and

the local electrode becomes useless. Here, electrons collide with the susceptor causing movement to be temporarily stopped.

Therefore, it is preferable to set the surface of the aforesaid local electrode exposed to plasma at the same height as the surface of the aforesaid base, or higher than the surface of this base by up to the width of the ion sheath (slightly high (0.1 to 1 mm)). In particular, a local electrode that has been set in the latter state does not become lower than the base, even when being sputtered, and there is the advantage that the performance can be maintained over a long period of time.

In addition, by making a distance between the local electrode and a part of the electrode I on which the base is mounted (susceptor) 101a longer than a distance that will be electrically short circuited, and shorter than a distance where movement of electrons generated on the local electrode no longer reach the base, the flow of electrons generated on the local electrode can be made smooth from the local electrode to the base.

In the present invention, a case in which the plasma density on a substrate within a uniform horizontal magnetic field is made uniform is cited as an example of the effect of using the aforementioned auxiliary electrode 102, but test results have also been obtained where the self-bias voltage on the base is non-uniform, even if the plasma in the vicinity of the base is uniform. This can be considered to be a problem caused due to a phenomenon where electrons move from the E pole to the W pole because of the horizontal magnetic field of the DRM, but as will be described later, this problem can be solved by applying a high frequency to an outer peripheral portion 107 of the electrode II in a state where a central portion 106 of the electrode II is at a ground potential.

<u>(2) Electrode II 105</u>

Figure 4 is a plan view of electrode II as viewed from the side of electrode I in Figure 1. The electrode II 105 pertaining to the present invention has a central portion 106 electrically grounded and an outer peripheral portion 107 connected to a high frequency power source (not shown), and is positioned opposite the electrode I 101. The characteristic feature of the electrode II pertaining to the present invention is that an electrode formed in an integral shape in the past is concentrically divided, and a high frequency power source that is separated from the high frequency power source to be applied to the electrode I can be input to an outer peripheral electrode. /17

In particular, when the concentrically divided electrode II is employed, by making a distance between the central portion and outer peripheral portion constituting the electrode II longer than a distance that will be electrically short circuited, it is possible to generate and maintain a stable plasma.

Moreover, it is favorable to make the distance between the aforesaid electrode I and the aforesaid outer peripheral portion of the electrode II, as well as the distance between the electrode II, the aforesaid electrode I and the aforesaid local electrode a distance, at least 0.1, at which a ratio obtained by dividing a minimum value by a maximum value of localized plasma density generated in the space sandwiched between the electrode I and electrode II because a stable plasma is obtained.

Furthermore, it is ideal to position an outer terminal of the base mounted on electrode I within a range from an outer edge to an inner edge of the outer peripheral portion constituting the electrode II, because a high uniformity of the self-bias potential on the base can be ensured.

In Figures 4 and 7, dividing of the outer peripheral portion 107 constituting the electrode II 105 into four parts has been done for tests that will be described later, but it can also be a single body. That is, as shown in Figure 36(a), the outer peripheral portion 107 constituting the electrode II 105 can be an integral body 107a having the same impedance.

In addition, as shown in Figure 36(b), the outer peripheral portion 107 constituting the electrode II 105 is a ring body, and can be provided with region of differing impedance so that the impedance of the ring body at a section 107b corresponding to an upstream side (E pole side) of a flow of electrons generated by application of a magnetic field is lower than at another region 107c.

As described above, the auxiliary electrode 102 (e.g., the local electrode 103 pertaining to the present invention was effective in engineering a uniform plasma density on the base in a uniform horizontal magnetic field, but there was a problem because the self-bias voltage for the base was not uniform, even if the plasma was uniform in the vicinity of the base.

However, with the electrode II 105 pertaining to the present /18
invention, the inner side electrode 106 shown in Figure 4 is at a ground potential and high frequency is applied to the outer side electrode 107, and by making the high frequency to be applied higher than that of electrode I, the problem where the self-bias potential Vdc for the base is not uniform even if plasma in the vicinity of the base is uniform can be solved.

Why a high frequency is not applied to both the inner side electrode 106 and the outer side electrode 107 but only to the outer side electrode 107 will be described. Figures 7 and 8 are model diagrams of electron flow when plasma is generated by the respective application systems. Figure 7 shows a case of the present invention where high frequency is only applied to the outer side electrode 107, and Figure 8 shows a conventional case in which high frequency is applied to both the inner side electrode 106 and the outer side electrode 107.

With the conventional system in Figure 8, the electron flow direction

is in an opposite direction of movement to electrode I 101 over the whole electrode II 105. However, with the system of the present invention in Figure 7 (high frequency applied to outer peripheral portion only), there is flow reverse to electrode I 101 at the outer peripheral portion 107 of the electrode II, but once they get to the E side edge, electrons join the electrode I side flow and can be considered to move once more to the W side. In this way, the electron flow for the surface of electrode II and the electron flow for the surface of electrode I form a single closed system, and this is one important characteristic feature of the present invention.

By using the system of the present invention in Figure 7, with plasma using a substantially uniform horizontal magnetic field of 120 gauss, a dispersion (max-min) in the self-bias potential Vdc that is normally a range of 20 to 30V in the prior art can be reduced to a few volts in the present invention. Thus, it is possible to almost completely eradicate wafer charge-up damage that constitutes a problem at the time of etching. This was solved in the prior art by causing the magnetic field to maintain a gradient, while it is significant that the present invention be able to solve the problem with a uniform horizontal magnetic field.

In short, with the conventional device, determining of a gradient condition for the sloping magnetic field was carried out by calculating an optimum magnetic field for a single process and forming the magnetic field. Since the optimum value varied according to processing conditions (pressure, raw gas material type, RF power, etc.), there were drawbacks because costs increased significantly and it lacked general-purpose applicability. Vis-à-vis, with the etching device pertaining to the present invention, the horizontal magnetic field does not affect the processing conditions as described above and a stable etching process can be constructed.

Here, the diameter of the inner side electrode 106 and the outer diameter of the outer side electrode 107 are respectively 160 mm and 260 mm when the size of the base to be processed is 200 mm, but naturally the advantages of the present invention are still obtained if various modifications are made to the diameter of the inner side electrode 106, etc. /19

Moreover, in the present invention, the high frequency input to the electrode I 101 was 13.56 MHz, while the high frequency input to the outer peripheral portion 107 of the electrode II was 100 MHz, but the high frequency input to the outer peripheral portion 107 of the electrode II can be any frequency as long as it is higher than that of the electrode I 101.

Furthermore, in the present invention, since the high frequency power applied to the outer peripheral portion 107 of the electrode II is set to a high frequency with respect to the frequency of electrode I (mainly, 13.56 or 27.12 MHz are used, but naturally the present invention is not limited to these two frequencies), the advantages of a comparatively lower power than the power of electrode I can be obtained. That is, when 13.56

MHz at 400 W is applied to electrode I, the applied power of 100 MHz to the outer peripheral portion 107 of electrode II for achieving Vdc correction effects will effectively be 75 to 100 W. This power is variously altered depending on the plasma conditions, but it can be said that the power that needs to be applied to the outer peripheral portion 107 of the electrode II is about 0.25 times the electrode I power.

(3) Mechanism for introducing process gas

A shower head 414, as shown in Figure 4, was employed as a mechanism for introducing process gas into the chamber 100. The shower head 414 has a plurality of process gas introduction pipes arranged in the central portion 106 of the electrode II 105 that is electrically grounded, and by injecting process gas from outside the plasma device 100 so that there is in-plane uniformity for the base 108 mounted on the electrode I, it is possible to maintain uniformity of gas flow in the vicinity of the base and a ratio of reaction by-product and raw material gas. This shower head serves an important function in the etching of an oxide film.

(4) Measures for supplying power from the two electrodes electrode I and electrode II (two-cycle excitation method)

In a two-cycle excitation method, the distance between the electrode I and the electrode II is important. In the present invention, this distance is set to 10 to 20 mm, and under these conditions the effect of /20
applying power to the electrode II of the present invention (outer peripheral portion of electrode II) is strikingly noticeable. However, in the event of large diameter bases of greater than 300 mm in the future, the flow of the process gas will progressively increase, high speed discharge of gas will become essential, and it would appear necessary to make the distance between the electrodes 30 mm or greater. In that case, the structure of the inner side electrode 106 and the outer side electrode 107 in Figure 4 is changed, as shown in Figure 9, and by providing members 107' and 107" so as to form a structure where only the outer side electrode 107 approaches the electrode I 101, the required speed of exhausting gas is achieved, while it becomes possible to carry out plasma correction.

By providing the aforementioned plasma etching device having the two electrodes electrode I and electrode II, it becomes possible to generate a uniform plasma at a level at which treatment of the base can be carried out using a uniform horizontal magnetic field without rotating the magnetic field, and it also is possible to reduce the overall size of the device, lower the cost and make it general purpose. Making the auxiliary electrode smaller also has the same effects of reducing the size of the device.

Practical Examples

The auxiliary electrode and plasma etching device pertaining to the present invention will now be described with reference to the drawings, but the present invention is not limited to these practical examples.

(Practical Example 1)

In this example, a parallel plate-type plasma etching device provided with the auxiliary electrode shown in Figure 1 is used, the plasma density distribution of plasma generated when a high frequency (13.56 (MHz)) is applied to electrode I was investigated with different methods of installing the auxiliary electrode.

The auxiliary electrode 102 used was divided into four parts, each part about one of the four poles (N pole, S pole, E pole and W pole) generated by the magnetic field-applying means 109. The effects of the auxiliary electrode of the present invention were then investigated with one auxiliary electrode (e.g., 102e) independently cathodized (i.e., electrically short circuited to the electrode I 101 and with the remaining three auxiliary electrodes (e.g., 102w, 102n and 102s) in a floating state.

The auxiliary electrode 102 is composed of the local electrode 103 comprising a conductive material (Al), and the junction impedance-adjusting means 104. A copper spacer is used as the junction impedance-adjusting means 104 when the local electrode 103 and the electrode I 101 are to be shorted, and a Teflon spacer is used when the local electrode 103 and the electrode I 101 are to be insulated. The local electrode 103 was /21 formed to be connected to the electrode I 101 via these spacers using a screw 112.

The inside of the chamber 100 had such a structure that it could be decompressed, and has been decompressed to a level of an ultimate vacuum 10^{-5} Pa by a turbo molecular pump (not shown). The raw material gas for generating plasma is introduced between two electrodes from a shower head provided at a central portion of the electrode II. In the present invention, argon gas was used as the raw gas material, and ion current density Jion (mA/cm^2) and self-bias potential Vdc (volts) were evaluated. Since the ion current density can be considered to be the plasma density, it will be referred to as plasma density hereafter. The gas pressure was adjusted in the range 10 of 200 mTorr depending on the gas flow rate.

The electrode II 105 is constructed as shown in Figure 4. That is, whereas it was constructed with a single plate in the conventional device, in the device of this example the electrode 106 of the central portion and the four outer peripheral electrodes 107 are separated. In this example, for the purpose of evaluating the auxiliary electrode, the electrode II was completely grounded as with the conventional device.

As shown in Figure 3, probes 113 for observing plasma were embedded in the electrode I 101 comprising a conductive material (SUS) at seventeen points within the plane of a 200 mm φ electrode (a diameter equivalent to a base and 8 inches φ). The Vdc was obtained by measuring the floating potential within the plasma for each of the embedded probes 113, and the plasma density Jion was obtained based on a current value which was measured

when probes were biased more negative than the already obtained Vdc.

Figures 10 to 13 are results of evaluating the plasma density Jion (mA/cm^2). Figure 10 shows a case in which only an E pole side local electrode 103e is cathodized; Figure 11 shows a case in which only a W pole side local electrode 103w is cathodized; Figure 12 shows a case in which only an N pole side local electrode 103n is cathodized; and Figure 13 shows a case in which only an S pole side local electrode 103s is cathodized, respectively. Here, making a local electrode a cathode means putting the local electrode of a prescribed pole side into a lower impedance state than the local electrodes of the other pole sides. In Figures 10 to 13, the horizontal axis is distance from the center of the base, while the vertical axis is plasma density Jion.

Also, the meaning of each of the symbols used in Figures 10 to 13 is shown in Table 1.

(Table 1) /22

図番	ｶｿｰﾄﾞ化した局所電極	記号	ｶｿｰﾄﾞ化の有無	プラズマ密度の測定方向
図10	E極側(302e)のみ	▲印	E極側のみｶｿｰﾄﾞ化	N極側～S極側
		△印	E極側のみｶｿｰﾄﾞ化	E極側～W極側
		●印	局所電極を全て非ｶｿｰﾄﾞ化	N極側－S極側
		○印	局所電極を全て非ｶｿｰﾄﾞ化	E極側～W極側
図11	W極側(302w)のみ	▲印	W極側のみｶｿｰﾄﾞ化	N極側～S極側
		△印	W極側のみｶｿｰﾄﾞ化	E極側～W極側
		●印	局所電極を全て非ｶｿｰﾄﾞ化	N極側～S極側
		○印	局所電極を全て非ｶｿｰﾄﾞ化	E極側～W極側
図12	N極側(302n)のみ	▲印	N極側のみｶｿｰﾄﾞ化	N極側～S極側
		△印	N極側のみｶｿｰﾄﾞ化	E極側～W極側
		●印	局所電極を全て非ｶｿｰﾄﾞ化	N極側～S極側
		○印	局所電極を全て非ｶｿｰﾄﾞ化	E極側～W極側
図13	S極側(302s)のみ	▲印	S極側のみｶｿｰﾄﾞ化	N極側－S極側
		△印	S極側のみｶｿｰﾄﾞ化	E極側～W極側
		●印	局所電極を全て非ｶｿｰﾄﾞ化	N極側～S極側
		○印	局所電極を全て非ｶｿｰﾄﾞ化	E極側－W極側

Key for Table 1:

Fig. No.	Local electrode that has been cathodized	Symbol	Presence/Absence of Cathodization	Direction of measuring plasma density
Figure 10	Only E pole side 302e	□	Only E pole side is cathodized	N pole side-S pole side
		♠	Only E pole side is cathodized	E pole side-W pole side
		□	All local electrodes not cathodized	N pole side-S pole side
		□	All local electrodes not cathodized	E pole side-W pole side
Figure 11	Only W pole side 302w	□	Only W pole side is cathodized	N pole side-S pole side
		♠	Only W pole side is cathodized	E pole side-W pole side
		□	All local electrodes not cathodized	N pole side-S pole side
		□	All local electrodes not cathodized	E pole side-W pole side
Figure 12	Only N pole side 302n	□	Only N pole side is cathodized	N pole side-S pole side
		♠	Only N pole side is cathodized	E pole side-W pole side
		□	All local electrodes not cathodized	N pole side-S pole side
		□	All local electrodes not cathodized	E pole side-W pole side
Figure 13	Only S pole side 302s	□	Only N pole side is cathodized	N pole side-S pole side
		♠	Only N pole side is cathodized	E pole side-W pole side
		□	All local electrodes not cathodized	N pole side-S pole side
		□	All local electrodes not cathodized	E pole side-W pole side

From these four graphs, it was seen that only when the E pole side is short circuited (Figure 10), the condition where the plasma density on the E pole side was lowered in the past could be corrected.

Figure 14 shows the results upon evaluating self-bias potential Vdc (volts) for a wafer. Figure 15 is a graph showing the collated results of the plasma densities Jion (mA/cm^2) shown in Figures 10 to 13. /23

From Figure 14, it was seen that in a case in which all the local electrodes were shorted (a condition corresponding to the conventional device), the Vdc and the etching rate both decreased. On the other hand, it was evident from Figures 14 and 15 that in a case in which only the E pole side local electrode (302e cathodized, a result was obtained where together with a Vdc of a certain size being obtained, the plasma density that would have lowered on the conventional E pole side now could be corrected. That is, it was seen that the above results were achieved by providing, for the base, an auxiliary electrode comprised of local electrodes and an impedance-adjusting means on at least at the upstream side (E pole side) of a flow of electrons generated by the magnetic field-applying means.

(Practical Example 2)

This example differs from Practical Example 1 in that the plasma density Jion (mA/cm^2) and self-bias potential Vdc (volt) were studied using capacitors of various capacitances as the means 104e for adjusting the junction impedance of the E pole side. Cases where the capacitance of the capacitor was 1, 7, 11 and 21 (pF) and a case in which the capacitor was shorted (Practical Example 1) were compared.

At this time, the other three means for adjusting junction impedance 104w, 104n and 104s) were allowed to float electrically.

The remaining points were the same as in Practical Example 1.

Figure 16 shows the results of evaluating the self-bias potential Vdc (volt) for a wafer, while Figure 17 shows the results of evaluating the plasma density Jion (mA/cm^2).

It was seen from these two graphs that by making the junction impedance on the E pole side an optimum value 21 (pF), a Vdc higher was attained than when there was a short, and the lower plasma density that would have occurred on the conventional E pole side now could be corrected.

(Practical Example 3)

In this example, the Vdc observed when a portion of the electrode II to which a high frequency power (100 (MHz)) was applied was changed was evaluated.

The remaining points were the same as for the conditions in Figure 10 of Practical Example 1 (only the E pole side cathodized). /24

Figure 18 is a graph showing the results of a case of application to all surfaces 106 and 107 of the electrode II; Figure 19 is a graph showing the results of a case of application to only a central portion 106 of the electrode II; Figure 20 is a graph showing the results of a case of application to only an outer peripheral electrode 107e of the E pole side; and Figure 21 is a graph showing results of a case of application to all outer peripheral electrodes 107. A schematic drawing of the electrode II is shown in the upper right portion of each drawing, and the blackened sections show the portions of the electrode to which a high frequency was applied.

In Figures 18 and 19, there was no dependence on the value of the applied power, the dispersion in the Vdc was large, and no effect for applying high frequency could be seen. In Figure 20, there was a tendency for the dispersion in the Vdc to be smaller than in Figures 18 and 19. In the case of Figure 21, it was evident that it was possible to significantly reduce the dispersion in the Vdc as compared to Figures 18 to 20. That is, it was confirmed that by applying a high frequency power to all outer

peripheral electrodes 107, it was possible to suppress the dispersion in the Vdc.

In addition from Figure 21, whereas there is dispersion in the Vdc of 20V or more and there is a risk of charge-up damage to the end surface of the base when the high frequency is not applied to the electrode II (Figure 21, 0W), in a case in which high frequency is applied to all the outer peripheral electrodes 107 of the electrode II (Figure 21, 75W), a dispersion in the Vdc can be checked to 3V; hence, charge-up damage can be reduced remarkably.

Figure 22 shows the results of a case of application to only the W pole side outer peripheral electrode 107w. Since this result has the same levels as for a case of application to only the E pole side outer peripheral electrode 107e shown in Figure 20, it can be considered that application to all outer peripheral electrodes 107 is essential in order to suppress a dispersion in the Vdc.

In this example, a high frequency power of 13.56 (MHz) is applied to the electrode I while a high frequency power of 100(MHz) is applied to the outer peripheral portion of the electrode II. But since the electrode II plays a role in regulating the generated plasma (functions as a means for adjusting the self-bias potential Vdc of the wafer), a frequency that is higher than the frequency f1 of the high frequency applied to the electrode I is used as the frequency f2 of the high frequency applied to the electrode II. As a result, Vdc correction effects can be obtained with a small input power. When f2 is higher in frequency than f1, it becomes difficult to sputter the electrode II because the Vdc for the electrode II decreases. Moreover, it is not preferable when the frequencies are the same (f2=f1), because the electrodes I and II interfere with one another and the plasma becomes unstable. However, it is possible to stabilize the plasma /25 even when f2=f1 by using a device to shift the phase of f1 and f2, among other devices.

(Practical Example 4)

In this example, in the device of Figure 1, distribution of the plasma density Ji on the base mounted on electrode I 101 was studied while altering the shape of the local electrode 103 comprising a conductive material constituting an auxiliary electrode 102 provided at least on the upstream side of a flow of electrons generated by the magnetic field-applying means and altering the relative arrangement of the disc-shaped base 108, and the uniformity of the plasma distribution was investigated. In that case, the shape of the local electrode 103 was arc shaped with respect to the disc-shaped base. Here, the straight line distance between both the base 108 side end sections of the local electrode 103 comprising the auxiliary electrode 102 was defined as L, and the diameter of the base 108 was defined as D, providing, in this example, a wafer having a diameter D of 200 mm was employed as the base.

The relative arrangement of the local electrode 103 and the base 108 was modified and the following four arrangements (Figures 29(a) to 29(d)) were verified by changing the length L of the arc shape of the local electrode opposite of the base.

Arrangement 4-1: a case in which the length L of the arc shape of the local electrode opposite the base is shorter than the diameter D of the base (Figure 29(a)).

Arrangement 4-2: a case in which the length L of the arc shape of the local electrode opposite the base is nearly the same as the diameter D of the base (Figure 29(b)).

Arrangement 4-3: a case in which the length L of the arc shape of the local electrode opposite the base is longer than the diameter D of the base (Figure 29(c)).

Arrangement 4-4: a case in which an auxiliary electrode is not provided, as with the conventional device (Figure 29(d)).

In the measurement of Ji above, probes provided on a section of the electrode I on which the base was mounted (susceptor 101a), as shown in Figure 30 (schematic plan view of the electrode I as viewed from the electrode II side), were employed (positions shown by the ○ in the drawings). That is, the probes were arranged in three stages in a linear manner from at least the upstream side (E pole side) of a flow of electrons generated by the magnetic field-applying means 109 to the downstream side (W pole side) in 20 mm intervals. The intervals between the three stages were 60 mm, and they were arranged so that the measurement line of the central stage passed through the center of the base. The number of probes thus arranged was 9 in the central stage, and 5 in the upper stage (N pole side) and the lower stage (S pole side), respectively.

In that case, it was necessary for the distance between the local electrode 103 and a section 101a of the electrode I on which the base was mounted to be longer than the distance at which an electrical short would occur, but shorter than a distance at which movement of ions generated at the local electrode did not reach the base; in this example it was set to 1 mm. /26

Also, the distance between the electrode I 101 and electrode II 105 was preferably a distance at which the ratio between the minimum value and the maximum value of the local plasma density generated within a space sandwiched between the electrode I and the electrode II became at least 0.1, but in this example it was set to 30 mm. A space where the plasma density was extremely low did not develop.

The remaining points were the same as at the conditions in Figure 10 of Practical Example 1 (only the E pole side cathodized).

Figures 31(a) to 31(d) are graphs showing results upon measuring the plasma density Ji at the four above-mentioned arrangements. Figures 31(a) to 31(d) show results for arrangements 4-1 to 4-4. In Figure 31, the horizontal axis is the position at which the probes are arranged, while the vertical axis is the self-bias potential Vdc. The three marks shown in the graphs have the following meanings. Δ represents the results of the upper stage measurement line; □ represents the results of the middle stage measurement line; and ∇ represents results of the lower stage measurement line.

The following points became evident from Figures 31(a) to 31(D).

(1) Compared to the arrangement 4-4 (a case in which the local electrode is not provided (Figure 29(d)), the arrangements 4-1 to 4-3 (Figures 29 (a) to 29(c)) having the local electrode 103 provided at least upstream exhibit a uniform plasma density for the middle measurement line, provided in a case of arrangement 4-1 (Figure 29(a)) where the length L of the arc shape of the local electrode opposite the base is shorter than the diameter D of the base, it was confirmed that plasma density was lower at the position of ☆.

(2) In arrangements 4-2 and 4-3 (Figures 29(b) and 29(c)) where the length L of the arc shape of the local electrode opposite the base is respectively the same as or larger than the diameter D of the base, there was uniform plasma density for the upper and lower measurement lines; hence, it was seen that it was possible to form a uniform and stable plasma over the entire surface of the base.

(Practical Example 5)

In this example, a parallel plate-type plasma etching device with no auxiliary electrode, as shown in Figure 32, was used in place of the device in Figure 1, and distribution of the self-bias potential Vdc on the base mounted on electrode I 101 was investigated while altering the relative arrangement of electrode II 105, where the central portion 106 and outer peripheral portion 107 were separated, and electrode I 101, and the uniformity of the self-bias potential was studied. In /27 Figure 32, 100 is a chamber; 101 is an electrode I; 101a is a section of the electrode I on which a base is mounted (susceptor); 105 is an electrode II; 106 is a central electrode; 107 is an outer peripheral electrode; 108 is a base; 109 is a magnetic field-applying means; 110 is a power source for applying high frequency to the electrode I; and 105 is a power source for applying a high frequency to the outer peripheral electrode constituting the electrode II.

Here, as shown in Figure 36(a), an integral member 107a having the uniform impedance was employed for the outer peripheral portion 107 constituting the electrode II 105 of the outer peripheral electrode constituting the electrode II.

In that case, a frequency of 13.56 MHz was applied to the electrode I 101 and a frequency of 100 MHz was applied to the electrode II 107, and the Vdc distribution on the base was studied for plasma generated when the central electrode 106 of the electrode II was set to an earth potential.

The following six arrangements (Figures 33(a) to 33(e)) were verified by changing the diameter of the central electrode 106, and the width of the outer peripheral electrode 107 with regards to changing the relative positions of the electrode II 105 and the electrode I 101.

Arrangement 5-1: a case in which the outer peripheral end of electrode I 101 is in the vicinity of the middle of the outer peripheral electrode 107 constituting the electrode II 105 (Figure 33(a)).

Arrangement 5-2: a case in which the outer peripheral end of the electrode I 101 is in the vicinity of the inner peripheral end of the outer peripheral electrode 107 constituting the electrode II 105 (Figure 33(b)).

Arrangement 5-3: a case in which the outer peripheral end of the electrode I 101 is in the vicinity of the outer peripheral end of the outer peripheral electrode 107 constituting the electrode II 105 (Figure 33(c)).

Arrangement 5-4: a case in which the outer peripheral end of the electrode I 101 is further in than the outer peripheral end of the central electrode 106 constituting electrode II 105 (Figure 33(d)).

Arrangement 5-5: a case in which the outer peripheral end of the electrode I 101 is further out than the outer peripheral end of the outer peripheral electrode 107 constituting the electrode II 105 (Figure 33(e)).

Arrangement 5-6: a case in which the electrode II 105 is composed only of a central electrode 106, and the outer peripheral end of the electrode I 101 is in the vicinity of the outer peripheral end of the central electrode 106 constituting the electrode II 105, as with the conventional device (Figure 33(f)). /28

In the measurement of the Vdc above, probes provided on a section of the electrode I on which the base was mounted (susceptor 101a), as shown in Figure 34 (schematic plan view of electrode I as viewed from the electrode II side), were used (positions shown by ○ in the drawings). That is, nine probes were arranged in a straight line in intervals of 20 mm from at least the upstream side (E pole side) of a flow of electrons generated by the magnetic field-applying means 109 to the downstream side (W pole side).

In that case, the interval between the central electrode 106 and the outer peripheral electrode 107 constituting the electrode II 105 had

to be longer than a distance at which electrical shorting would occur, and in this example, it was set to 1 mm.

In addition, the distance between the electrode I 101 and the outer peripheral section 107 of the aforesaid electrode II was preferably a distance at which a ratio between the minimum value and a maximum value of the local plasma density generated within a space sandwiched between the electrode I and the electrode II became at least 0.1, and in this example it was set to 30 mm. Thus, a space did not develop where the plasma density was extremely low.

Figure 35 is a graph showing the results upon measuring the self-bias potential Vdc in the above-mentioned six arrangements. In Figure 35, △ represents an arrangement 5-1; the ■ represents an arrangement 5-2; ○ represents an arrangement 5-3; ▽ represents an arrangement 5-4; ◇ represents an arrangement 5-5; and × represents an arrangement 5-6.

The following points became evident from Figure 35.

(1) Whereas the arrangement 5-6 (a case in which no outer peripheral electrode is provided and the electrode II only is composed of a central electrode (×) where the Vdc distribution (distance between the maximum and minimum values) is about 20 volts, with arrangements 5-1 to 5-5 provided with an outer peripheral electrode to which a high frequency is applied, the Vdc is uniform in the direction from the E pole side to the W pole side, and the Vdc distribution is less than about 10 volts.

(2) With the arrangements 5-1 to 5-3 having the outer peripheral end of the electrode I 101 provided within the range of the width of the outer peripheral electrode 107 constituting the electrode II 105, it was seen that a dispersion in the Vdc from the E pole side to the W pole side could be suppressed to less than about 5 volts. As a result, charge-up damage to the base can be reduced remarkably.

Moreover, in this example, a case in which the central electrode 106 of the electrode II was set to an earth potential was exemplified, but is was confirmed that the same effects as in this example could also be obtained in a case in which the central electrode 106 of the electrode II was floating. Consequently, there is no problem if the central /29 electrode 106 of the electrode II is either an earth potential or it is floating.

Furthermore, in this example, as shown in Figure 36(a), an integral member 107a having the same impedance was used for the outer peripheral electrode 107 constituting the electrode II 105 of the outer peripheral electrode constituting the electrode II, but it was confirmed that nearly the same effects as in Figure 35 above were obtained even if a region having different impedances were provided as long as the outer peripheral section 107 constituting the electrode II 105 was a ring body, as shown in Figure 36(b), and a region having a different impedance was provided

so that the impedance of this ring body was lower at a region 107b corresponding to the upstream side (E pole side) of a flow of electrons generated by the magnetic field-applying means than at the other section 107c).

Industrial Applicability

As described above, according to the present invention, there is provided an auxiliary electrode capable of planning that the density of the plasma generated on the surface of a base is made uniform.

By providing the auxiliary electrode of the present invention on the outer periphery of the electrode I on which the base is mounted, it a plasma etching device capable of uniform etching or sputtering over the entire surface of a base can be constructed.

Furthermore, by applying high frequency power to only an outer peripheral section of an electrode II positioned opposite the electrode I, it is possible to provide a plasma etching device wherein the self-bias potential of a base is made uniform.

Claim(s) /30

1. A plasma etching device provided with two parallel plate-type electrodes I and II and a means for applying high frequency power connected to said electrode I and/or electrode II; a base on which an etching treatment is to be performed using plasma is mounted on a surface of the electrode I opposite the electrode II; and a means for applying a unidirectional magnetic field that is horizontal to the surface of the aforesaid base to be subjected to plasma etching; said plasma etching device characterized by providing an auxiliary electrode at least on the upstream side, with respect to the base, of a flow of electrons generated by the magnetic field-applying means; said auxiliary electrode being composed of a local electrode arranged on a side facing the electrode II and a means for adjusting the impedance provided at a part of the local electrode electrically connected to the electrode I.

2. A plasma etching device provided with two parallel plate-type electrodes I and II, and a means for applying a high frequency power connected to said electrodes I and II; a base on which an etching treatment is to be performed using plasma mounted on a surface of the aforesaid electrode I opposite the aforesaid electrode II; and a means for applying a unidirectional magnetic field that is horizontal to the surface of the base to be subjected to plasma etching; said plasma etching device /31
characterized by the aforesaid electrode II being composed of a central portion grounded electrically, and an outer peripheral portion connected to a high frequency power supply capable of being suppressed independent of a high frequency power supply connected to the aforesaid electrode I.

3. A plasma etching device provided with two parallel plate-type electrodes I and II, and a means for applying a high frequency power connected to said electrodes I and II; a base on which an etching treatment is to be performed using plasma mounted on a surface of the aforesaid electrode I opposite the aforesaid electrode II; and a means for applying a unidirectional magnetic field that is horizontal to the surface of the base to be subjected to plasma etching; said plasma etching device characterized by providing an auxiliary electrode at least on the upstream side of a flow of electrons generated by the aforesaid magnetic field-applying means; said auxiliary electrode being composed of a local electrode arranged on a side opposite the aforesaid electrode II, and a means for adjusting the impedance provided at a part of said local electrode connected electrically to the aforesaid electrode I; and the aforesaid electrode II being composed of a central portion grounded electrically and an outer peripheral portion connected to a high frequency power supply capable of being suppressed independent of a high frequency power supply connected to the aforesaid electrode I.

4. The plasma etching device of any one of Claim 1 or 3 characterized by the aforesaid magnetic field-applying means being a dipole ring magnet (DRM).

5. The plasma etching device of Claim 1 or 3 characterized by the local electrode constituting the aforesaid auxiliary electrode being a 1^{st} local electrode comprising a conductive material provided only on the upstream side of a flow of electrons generated by the aforesaid magnetic field-applying means.

6. The plasma etching device of Claim 1 or 3 characterized by the local electrode constituting the aforesaid auxiliary electrode comprising a combination of a 2^{nd} local electrode comprising a conductive material provided at least on an upstream side of a flow of electrons generated by the aforesaid magnetic field-applying means, and a 3^{rd} local electrode comprising an insulating material provided except on said upstream side.

7. The plasma etching device of Claim 1 or 3 characterized by the aforesaid local electrode constituting the auxiliary electrode comprising a combination of a 4^{th} local electrode comprising a conductive material that is wide at least at an upstream side of a flow of electrons generated by the magnetic field-applying means and narrow except on the upstream side, and a 5^{th} local electrode comprising an insulating material provided outside a region where the 4^{th} electrode is narrow, as viewed from the base side.

8. The plasma etching device of Claim 1 or 3 characterized by the aforesaid local electrode constituting the auxiliary electrode provided at least on the upstream side of the flow of electrons generated by the aforesaid magnetic field-applying means.

9. The plasma etching device of Claim 1 or 3 characterized by the aforesaid means for adjusting the joint impedance having an uneven /32
shape provided in the region of the aforesaid local electrode connected electrically to the aforesaid electrode I.

10. The plasma etching device of Claim 1 or 3 characterized by the aforesaid means for adjusting the joint impedance having an uneven shape provided in the region of the aforesaid electrode I connected electrically to the aforesaid local electrode.

11. The plasma etching device of Claim 1 or 3 characterized by the aforesaid means for adjusting the joint impedance being a monolayer film or a laminated film provided between the aforesaid local electrode and the aforesaid electrode I and comprising a material having a different dielectric constant than said local electrode and said electrode I.

12. The plasma etching device of Claim 1 or 3 characterized by the aforesaid means for adjusting the joint impedance being a cavity provided inside the aforesaid local electrode.

13. The plasma etching device of Claim 1 or 3 characterized by the aforesaid means for adjusting the joint impedance being a cavity provided

in the vicinity of the interface between the aforesaid local electrode and the aforesaid electrode I.

14. The plasma etching device of Claim 12 or 13 characterized by the inside of the aforesaid cavity being either of a vacuum, an inert gas, or a material having a different dielectric constant from the aforesaid local electrode and the aforesaid electrode I.

15. The plasma etching device of Claim 12 or 13 characterized by the aforesaid means for adjusting the joint impedance being a capacitor provided between the aforesaid local electrode and the aforesaid electrode I.

16. The plasma etching device of Claim 1 or 3 characterized by the material composing the aforesaid local electrode being any of Al, Cu, Si, SiC, or glassy carbon.

17. The plasma etching device of Claim 1 or 3 characterized by the surface of the aforesaid local electrode to be exposed to plasma being at the same height as the surface of the aforesaid base, or higher than the surface of this base by up to the width of the ion sheath.

18. The plasma etching device of Claim 1 or 3 characterized by the aforesaid local electrode and a part of the aforesaid electrode I on which the base is mounted being longer than a distance that will be electrically short circuited, and shorter than a distance where movement of /33
electrons generated on the local electrode no longer reach the base.

19. The plasma etching device of Claim 1 characterized by the outer peripheral end of the base mounted on the aforesaid electrode I being arranged the same as the outer peripheral end of the aforesaid electrode II, or on the inside thereof.

20. The plasma etching device of Claims 2 or 3 characterized by the distance between the aforesaid electrode I and the outer peripheral portion of the aforesaid electrode II being made a distance where the movement of the electrons generated on the respective surfaces of said electrode I and said electrode II affecting one another.

21. The plasma etching device of Claims 2 or 3 characterized by the distance between the central portion and the outer peripheral portion constituting the aforesaid electrode II being longer than the distance that will be electrically short circuited.

22. The plasma etching device of Claims 2 or 3 characterized by the outer peripheral end of the base mounted on the aforesaid electrode I being arranged within the range of the inner peripheral end from the outer peripheral end of the outer peripheral portion constituting the aforesaid electrode II.

23. The plasma etching device of any one of Claims 1 to 3 characterized by having a shower head comprising a plurality of process gas introduction pipes arranged in a region of said electrode II that is grounded electrically as a mechanism for introducing a process gas into the space sandwiched between the aforesaid electrode I and aforesaid electrode II.

24. The plasma etching device of Claim 2 or 3 characterized by the relationship between the frequency f1 of the high frequency applied to said electrode I, and the frequency f2 of the high frequency applied to said electrode II being $f1 \leqq f2$, when a high frequency is applied locally to the aforesaid electrode I and aforesaid electrode II and the base mounted on said electrode I is subjected to plasma etching.

25. A plasma etching device provided with two parallel plate-type electrodes I and II and a means for applying high frequency power connected to said electrode I and/or electrode II; a base on which an etching treatment is to be performed using plasma is mounted on a surface of the electrode I opposite the electrode II; and a means for applying a unidirectional magnetic field that is horizontal to the surface of the aforesaid base to be subjected to plasma etching; said plasma etching device /34 characterized by said auxiliary electrode being composed of a local electrode arranged on the side facing the aforesaid electrode II, and a means for adjusting impedance provided in a part of said local electrode connected electrically to the aforesaid electrode I; and the impedance of the aforesaid ring body being lower in a part corresponding to the upstream side of the flow of electrons generated by the aforesaid magnetic field-applying means being lower than in the remaining parts.

26. A plasma etching device provided with two parallel plate-type electrodes I and II and a means for applying high frequency power connected to said electrode I and/or electrode II; a base on which an etching treatment is to be performed using plasma is mounted on a surface of the electrode I opposite the electrode II; and a means for applying a unidirectional magnetic field that is horizontal to the surface of the aforesaid base to be subjected to plasma etching; said plasma etching device characterized by the aforesaid electrode II being composed of a central portion that is grounded electrically, and an outer peripheral portion connected to a high frequency power supplying capable of being suppressed independent of the high frequency power supply connected to the aforesaid electrode I; and the impedance of the aforesaid ring body being lower in a part corresponding to the upstream side of a flow of electrons generated by the aforesaid magnetic field-applying means than in the remaining parts.

Figure 1

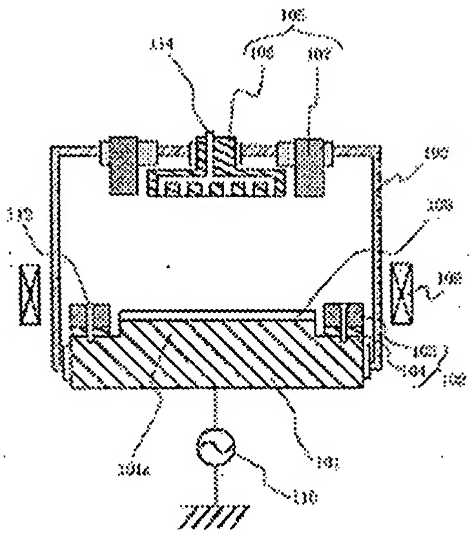


Figure 2

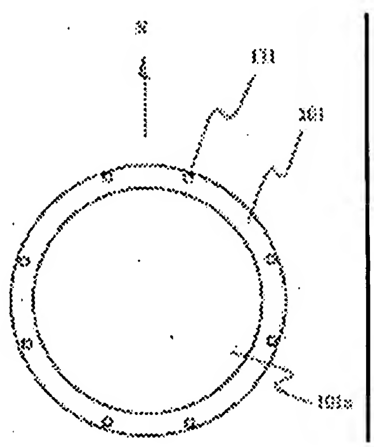


Figure 3

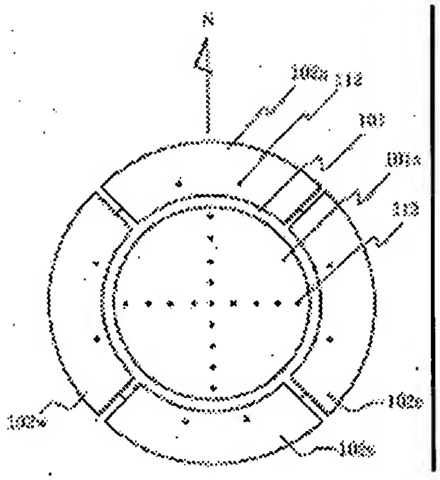
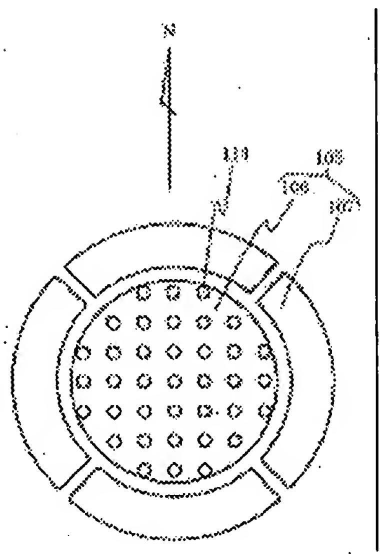
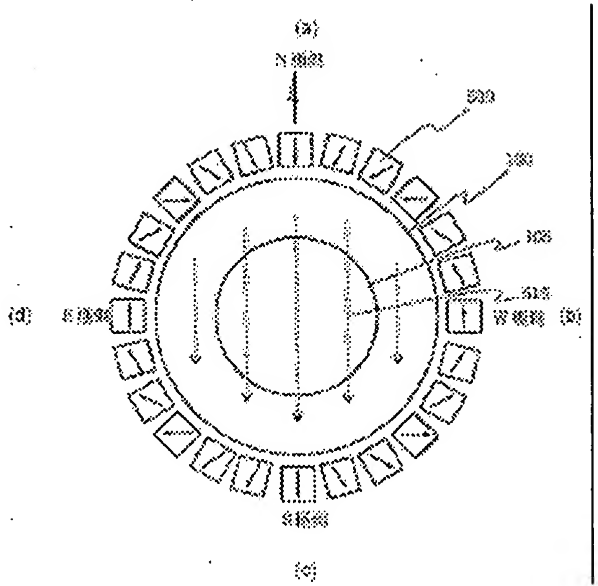


Figure 4



/3/34

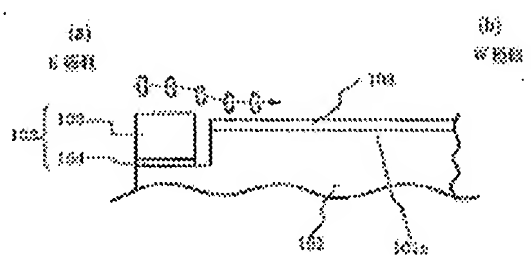
Figure 5



Key: (a) N pole side; (b) W pole side; (c) S pole side; (d) E pole side

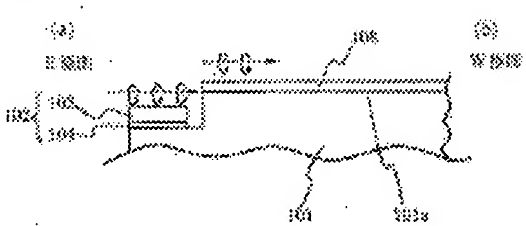
Figure 6

(a)



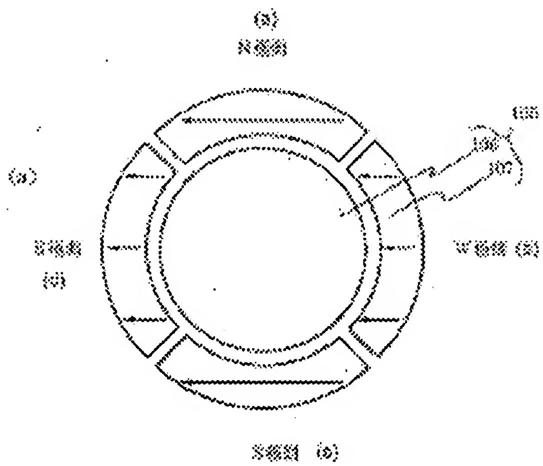
Key: (a) E pole side; (b) W pole side

(b)

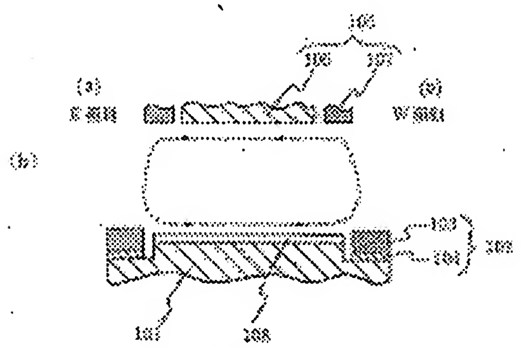


Key: (a) E pole side; (b) W pole side

Figure 7 /6/34

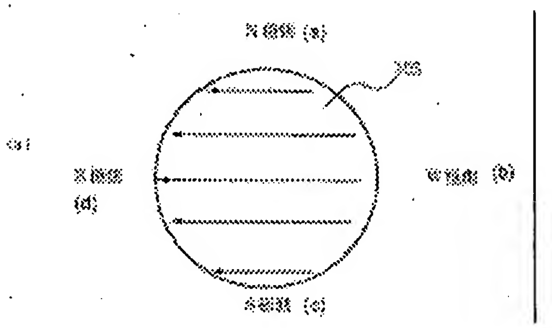


Key: (a) N pole side; (b) W pole side; (c) S pole side; (d) E pole side

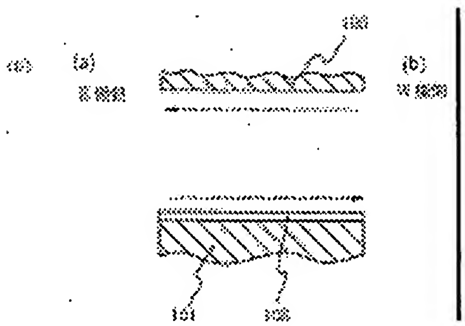


Key: (a) E pole side; (b) W pole side

Figure 8 /7/34



Key: (a) N pole side; (b) W pole side; (c) S pole side; (d) E pole side



Key: (a) E pole side; (b) W pole side

Figure 9 /8/34

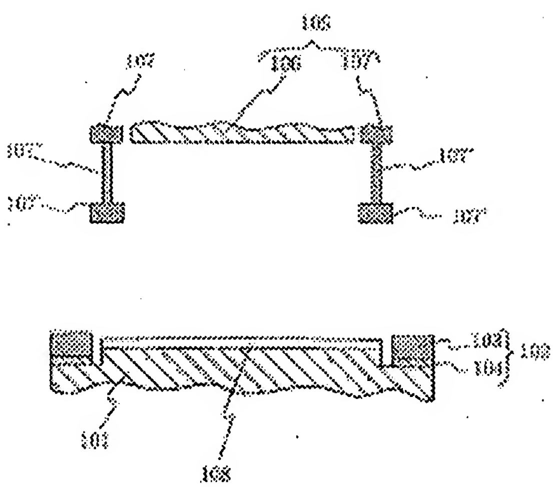
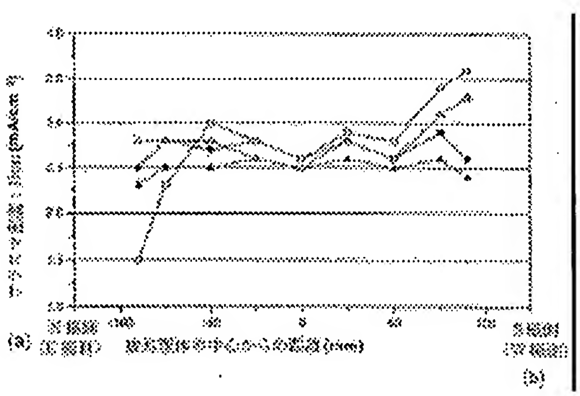
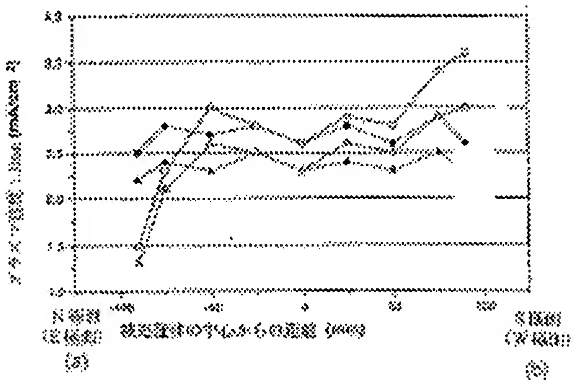


Figure 10 /9/34



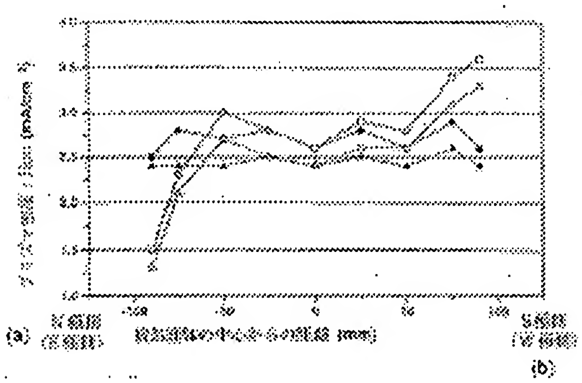
Key: (a) N pole side (E pole side); (b) S pole side (W pole side); (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Plasma Density

Figure 11



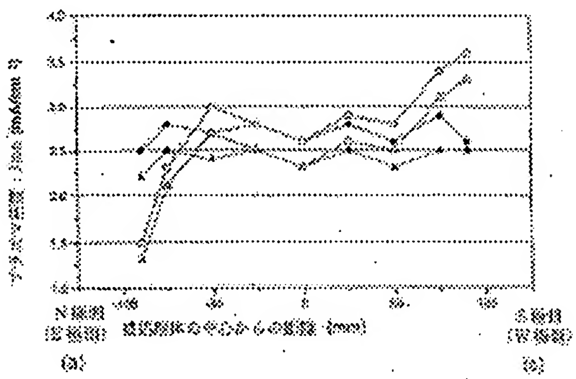
Key: (a) N pole side (E pole side); (b) S pole side (W pole side); (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Plasma Density Ion (mA/cm ²)

Figure 12 /10/3



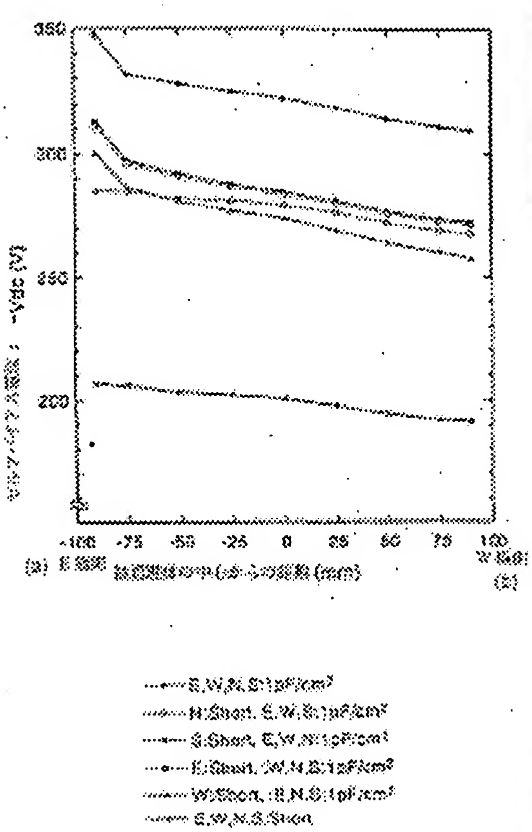
Key: (a) N pole side (E pole side); (b) S pole side (W pole side); (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Plasma Density Ion (mA/cm ²)

Figure 13



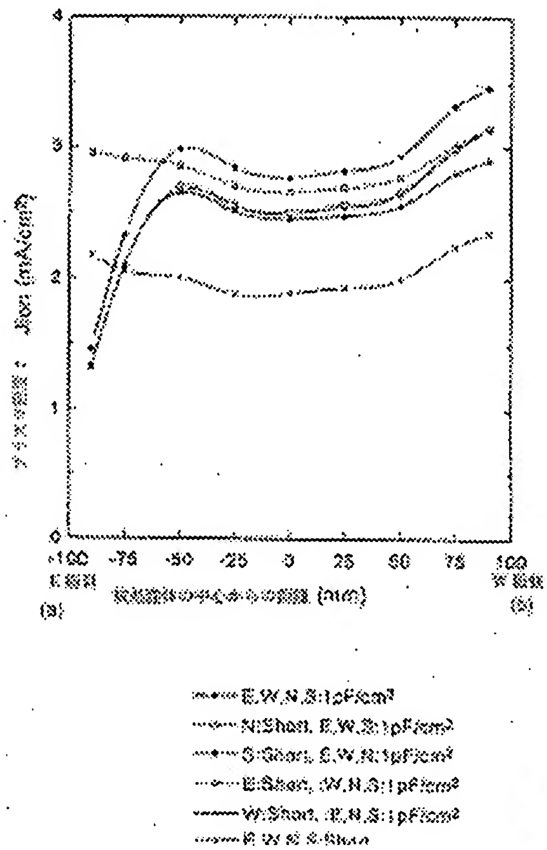
Key: (a) N pole side (E pole side); (b) S pole side (W pole side); (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Plasma Density Jion (mA/cm²)

Figure 14 /11/3



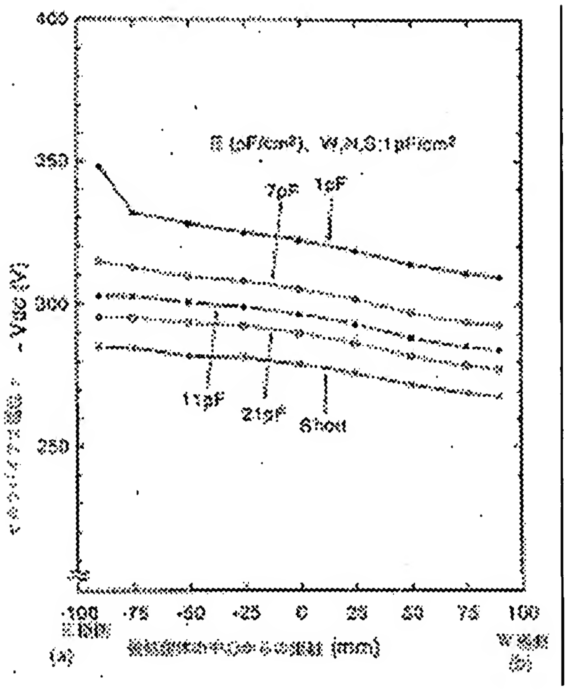
Key: (a) E pole side; (b) W pole side; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Self-Bias Potential -Vdc (V)

Figure 15



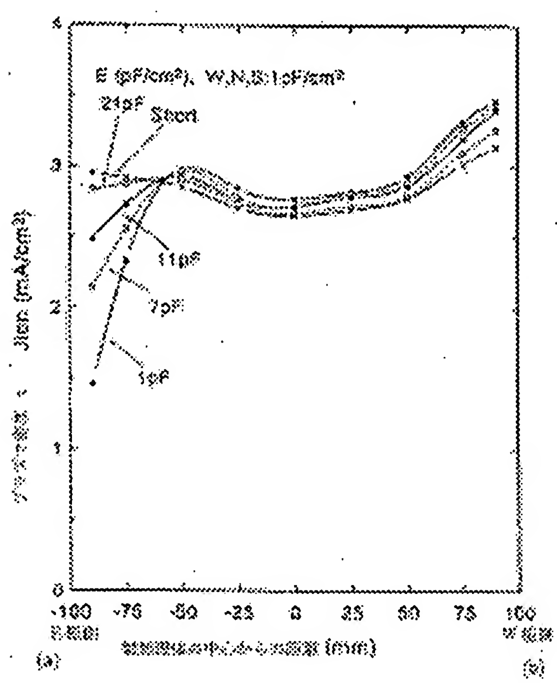
Key: (a) E pole side; (b) W pole side; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Plasma Density Jion (mA/cm ²)

Figure 16 /13/3



Key: (a) E pole side; (b) W pole side; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Self-Bias Potential -Vdc (V)

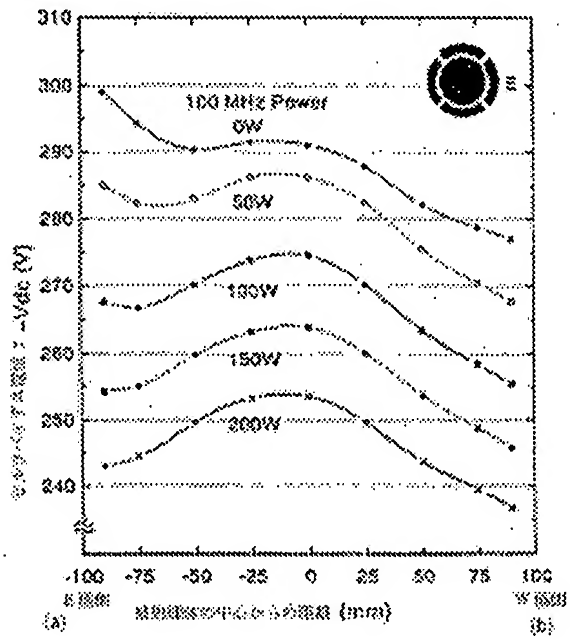
Figure 17 /14/3



Key: (a) E pole side; (b) W pole side; (X axis) Distance (mm) From Center

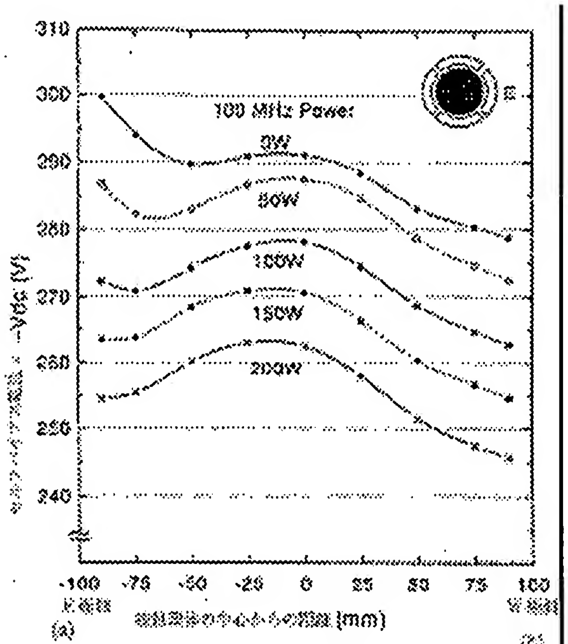
of Object to be Treated; (Y axis) Plasma Density Jion (mA/cm 2)

Figure 18 /15/3



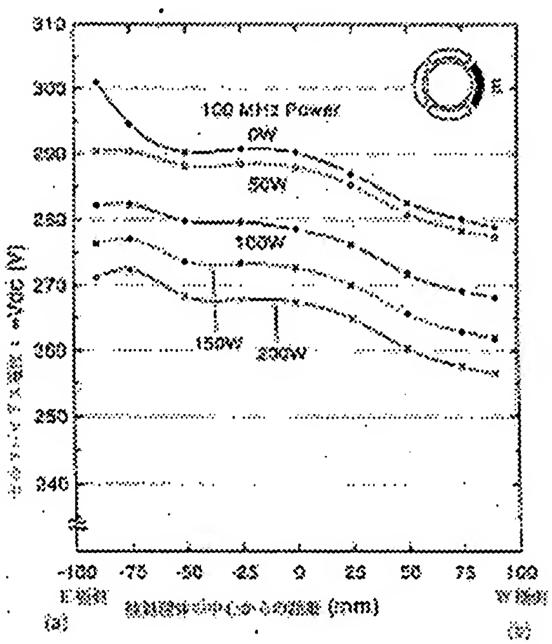
Key: (a) E pole side; (b) W pole side; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Self-Bias Potential -Vdc (V)

Figure 19 /16/3



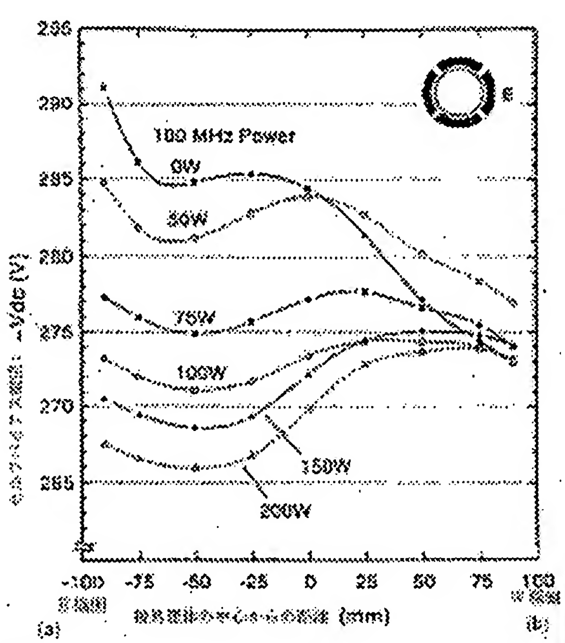
Key: (a) E pole side; (b) W pole side; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Plasma Density Jion (mA/cm 2)

Figure 20 /17/3



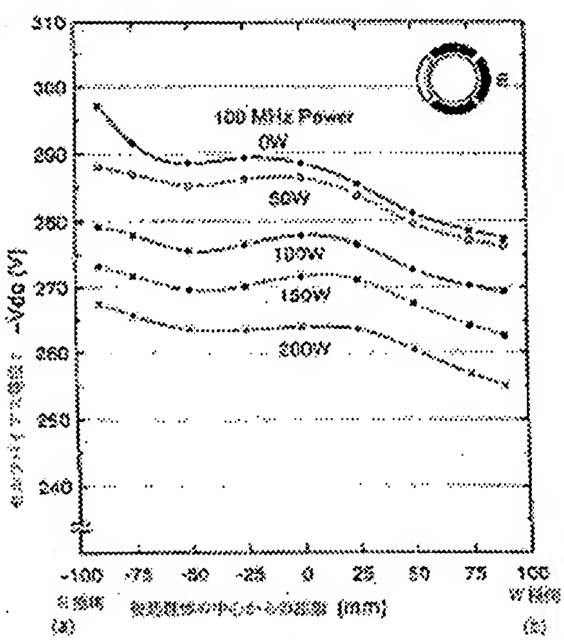
Key: (a) E pole side; (b) W pole side; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Self-Bias Potential -Vdc (V)

Figure 21 /18/3



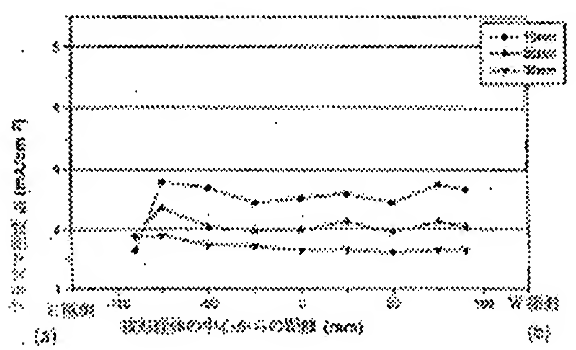
Key: (a) E pole side; (b) W pole side; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Self-Bias Potential -Vdc (V)

Figure 22 /19/3



Key: (a) E pole side; (b) W pole side; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Self-Bias Potential −Vdc (V)

Figure 23 /20/3



Key: (a) E pole side; (b). W pole side; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Plasma Density Jion(mA/cm 2)

Figure 24 /21/3

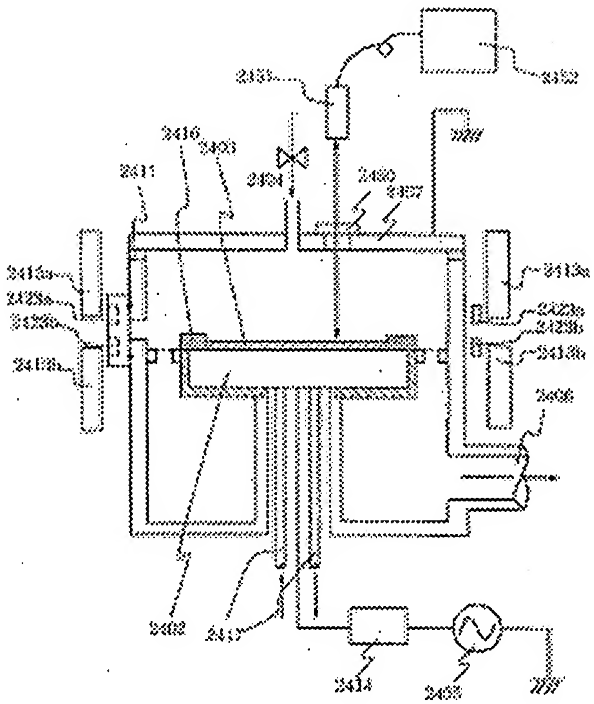
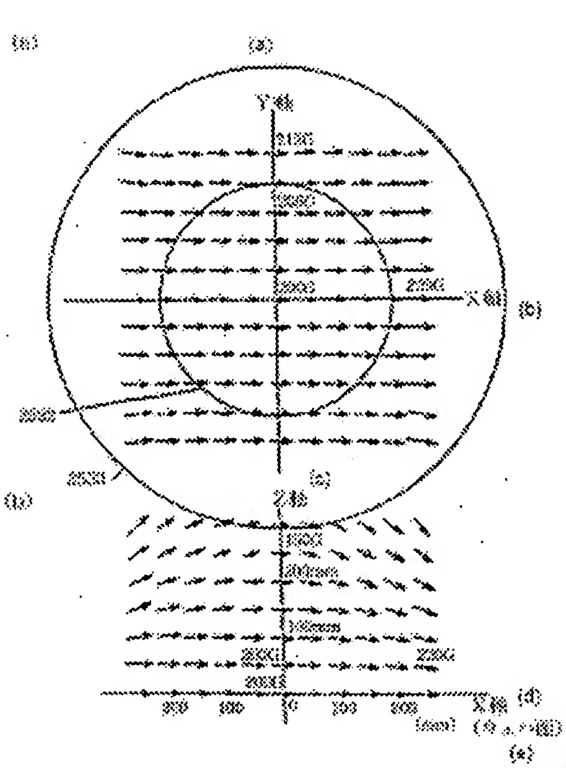


Figure 25 /22/3



Key: (a) Y axis; (b) X axis; (c) Z axis; (d) X axis; (e) Wafer Surface

Figure 26

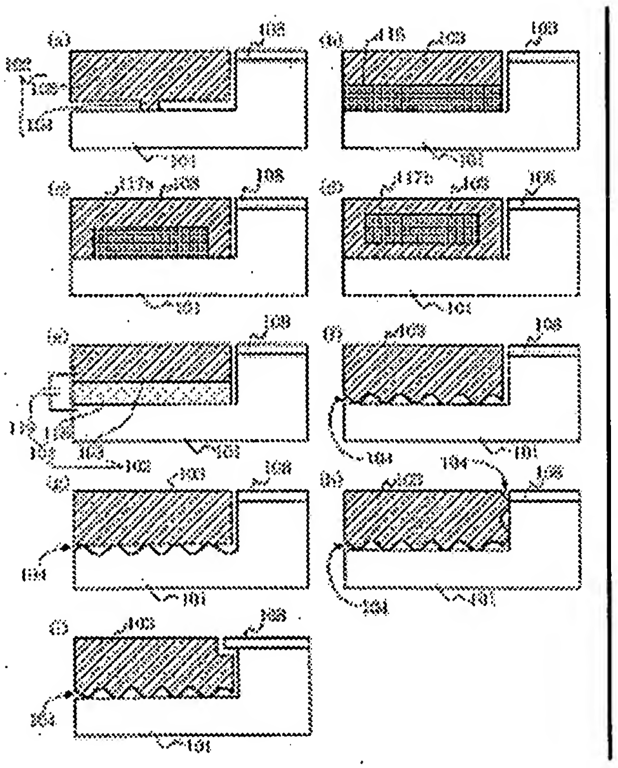
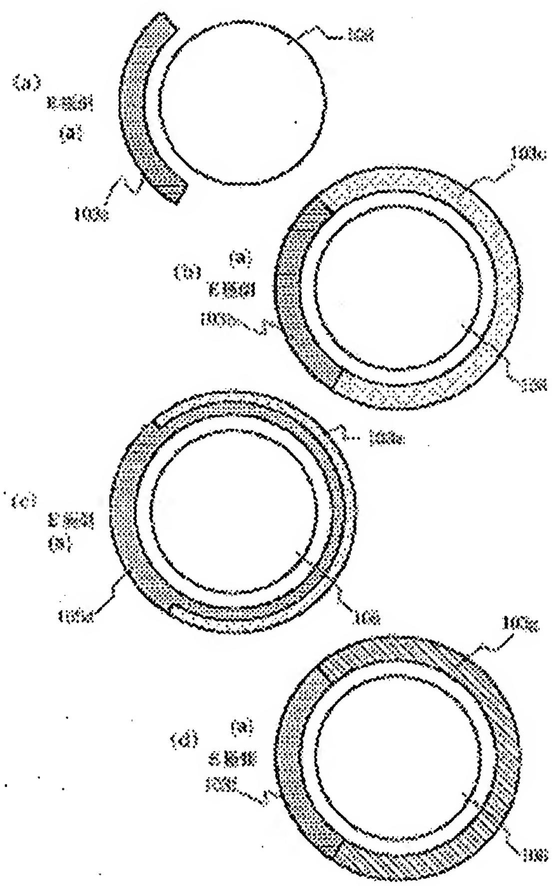


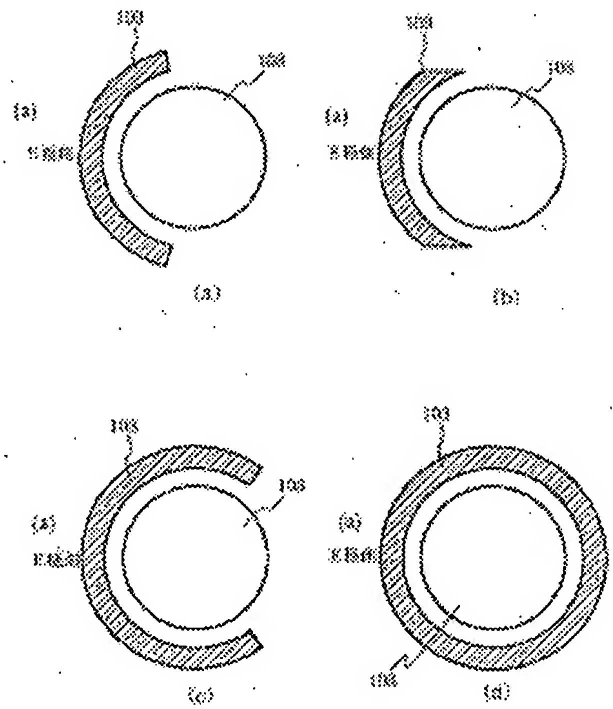
Figure 27

/24/3



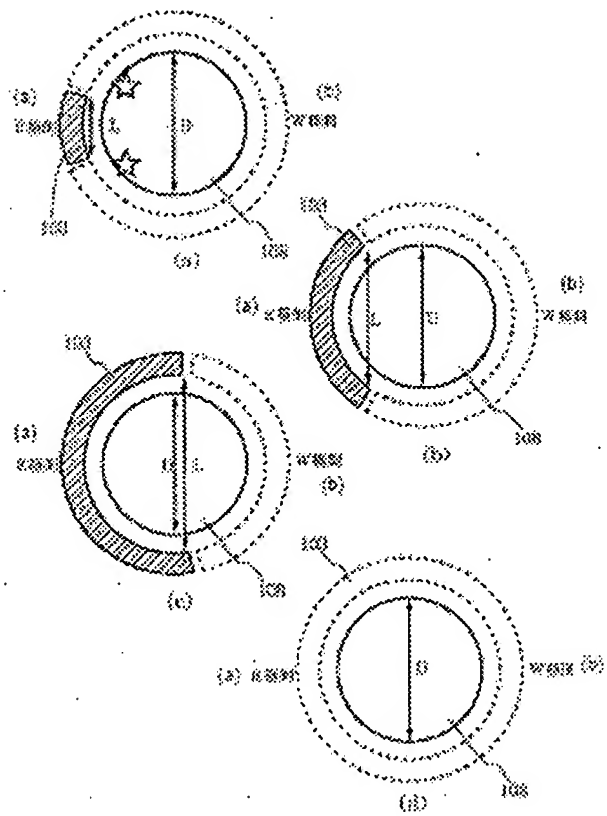
Key: (a) E pole axis

Figure 28 <u>/25/3</u>



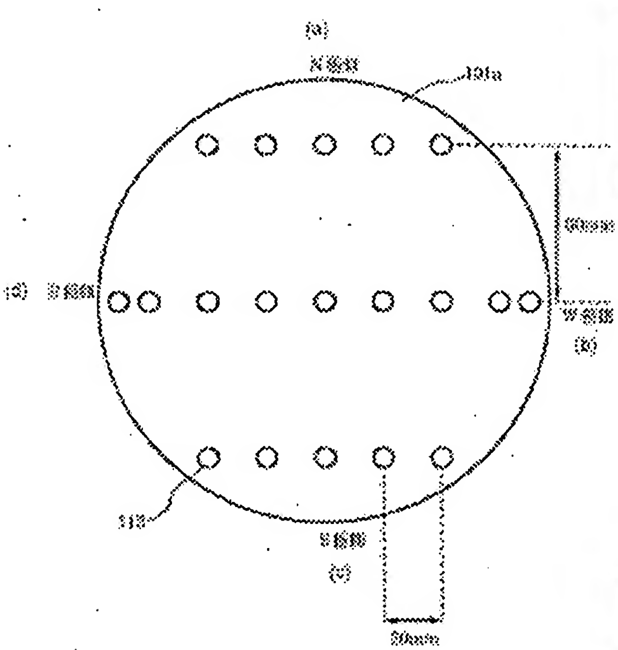
Key: (a) E pole axis

Figure 29



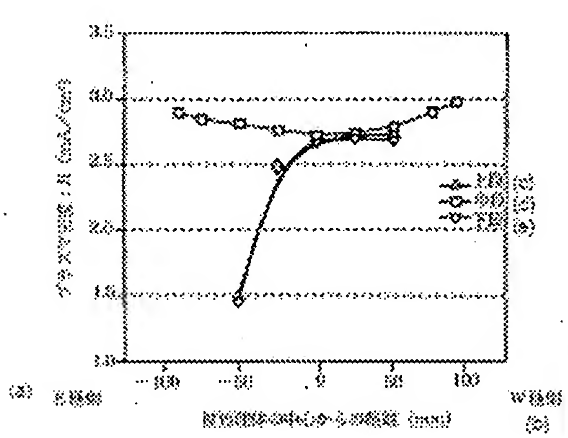
Key: (a) E pole axis; (b) W pole axis

Figure 30 /27/3



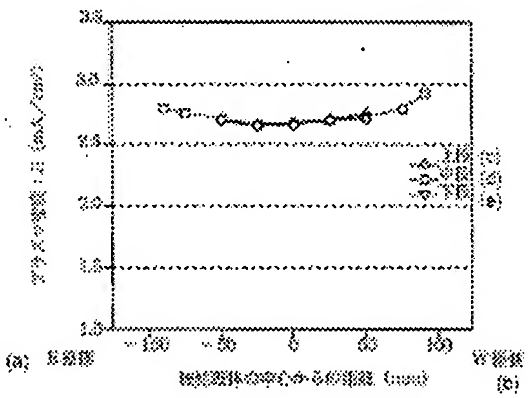
Key: (a) N pole axis; (b) W pole axis; (c) S pole axis; (d) E pole axis

Figure 31(a) /28/3



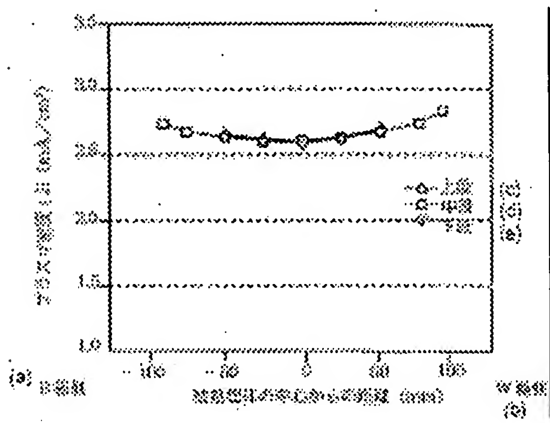
Key: (a) E pole axis; (b) W pole axis; (c) upper stage; (d) central stage; (e) lower stage; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Plasma Density Jion (mA/cm ^{2})

Figure 31(b)



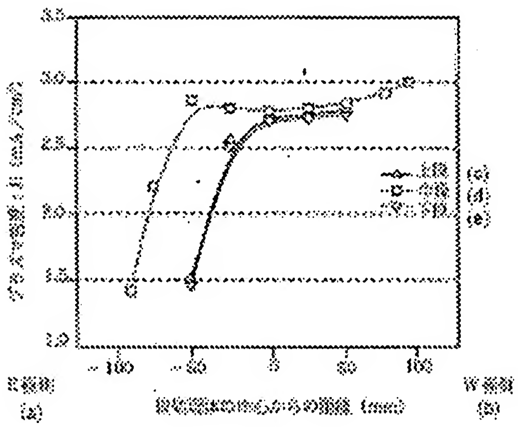
Key: (a) E pole axis; (b) W pole axis; (c) upper stage; (d) central stage; (e) lower stage; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Plasma Density Jion (mA/cm ²)

Figure 31(c) /29/3



Key: (a) E pole axis; (b) W pole axis; (c) upper stage; (d) central stage; (e) lower stage; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Plasma Density Jion (mA/cm ²)

Figure 31(d)



Key: (a) E pole axis; (b) W pole axis; (c) upper stage; (d) central stage; (e) lower stage; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Plasma Density

Figure 32 /30/3

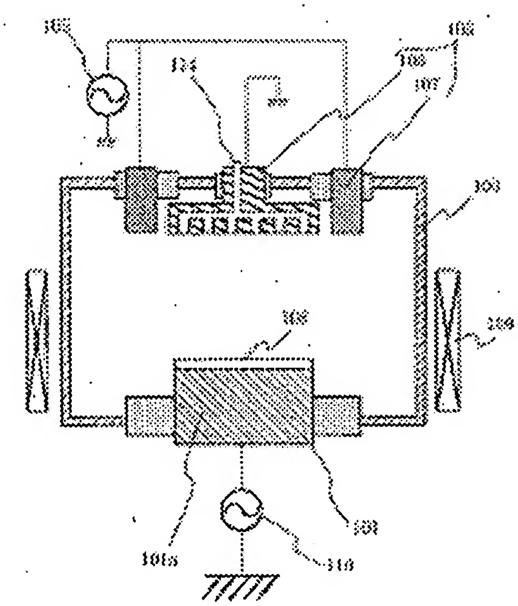


Figure 33 /31/3

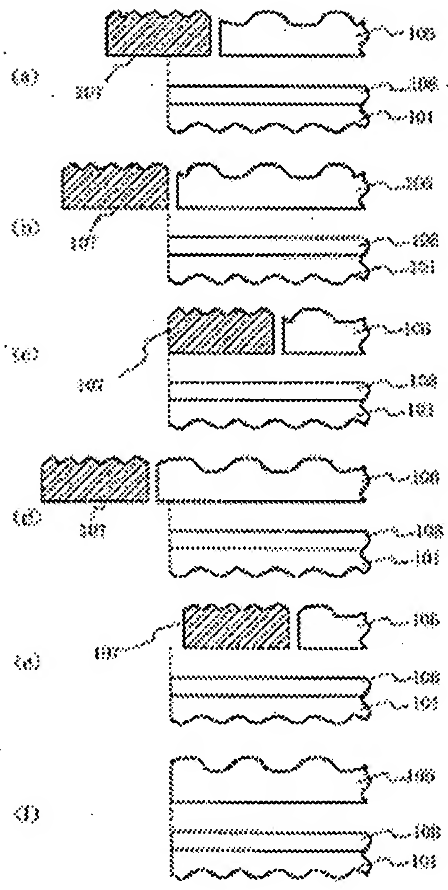
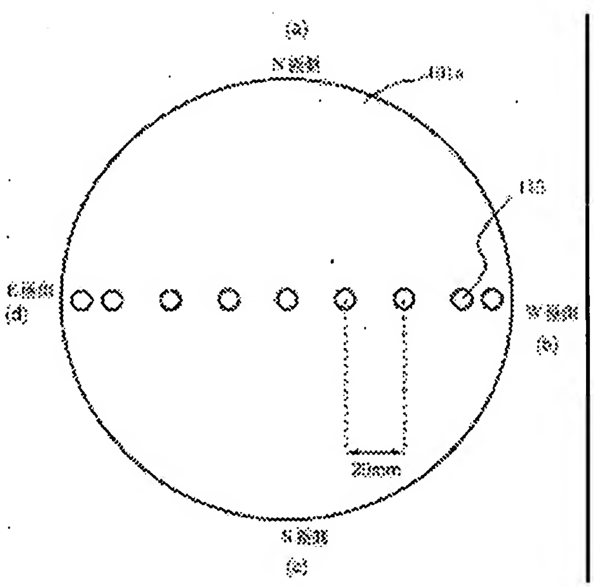
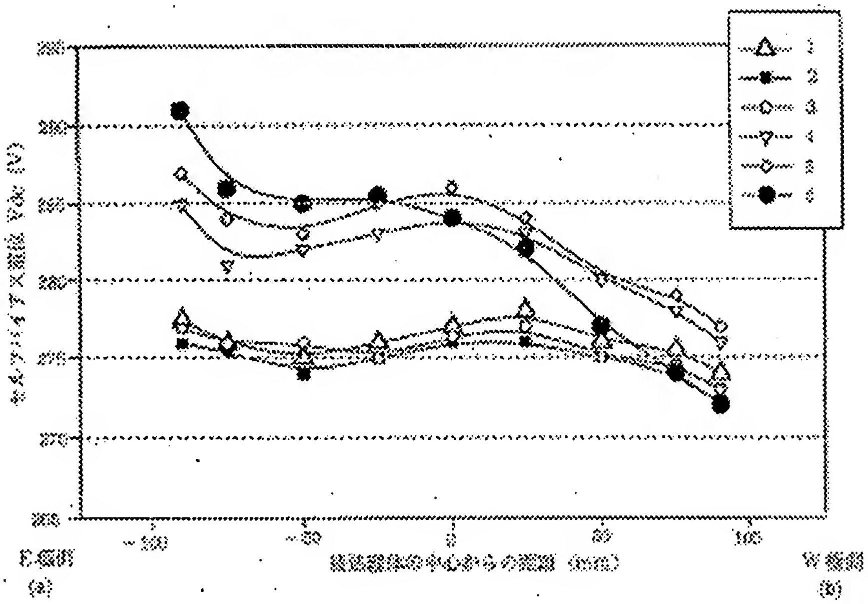


Figure 34 /32/3



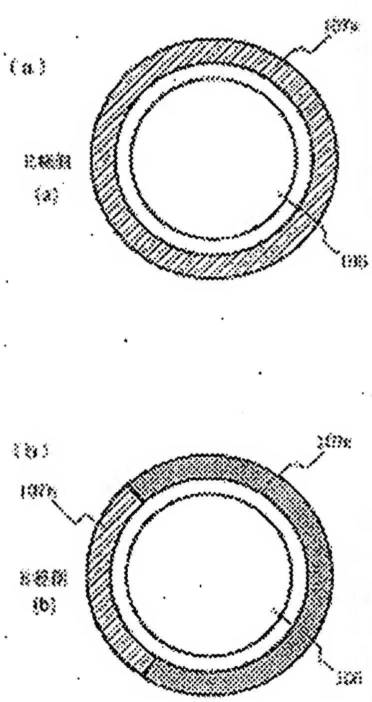
(a) N pole side; (b) W pole side; (c) S pole side; (d) E pole side

Figure 35 /33/3



Key: (a) E pole side; (b) W pole side; (X axis) Distance (mm) From Center of Object to be Treated; (Y axis) Self-Bias Potential -Vdc (V)

Figure 36 /34/3



Key: (a) E pole side; (b) E pole side